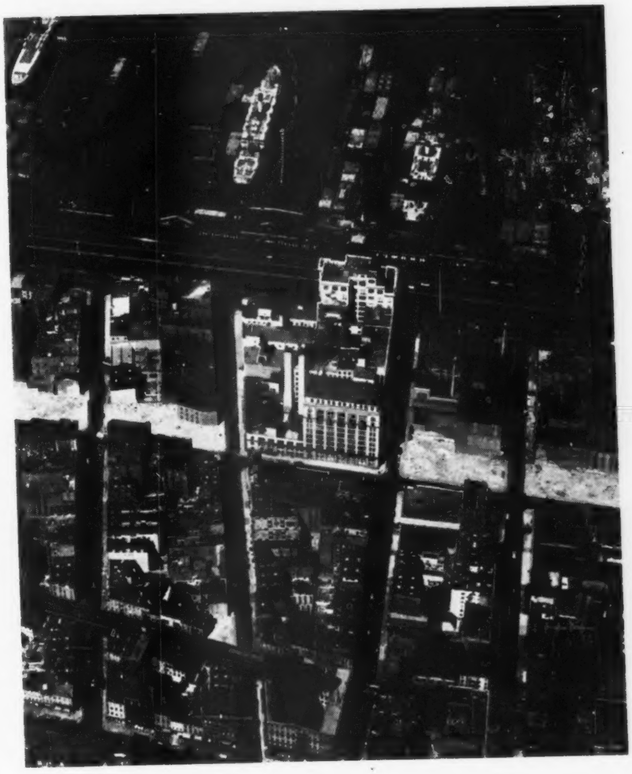
BELL LABORATORIES RECORD



September 1931 to August 1932

VOLUME X

Bell Laboratories Record

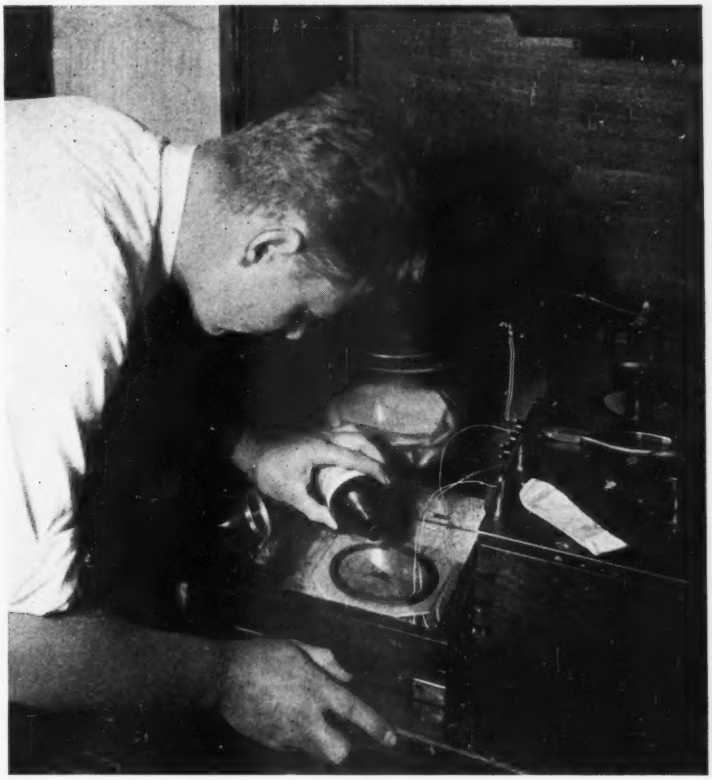
Edited by the Bureau of Publication:

Paul B. Findley, *Managing Editor*
Philip C. Jones, *Associate Editor*

Bell Telephone Laboratories, Incorporated
463 West Street, New York, N. Y.

List of Issues in Volume X

BELL LABORATORIES RECORD



Pouring a mercury electrode is an incident of measuring the dielectric constant of an insulating material. When determinations at high frequencies are involved (in this case, 700,000 cycles), work of this nature is done by the Electrical Measurements group of the Telephone Apparatus Development Department

VOLUME TEN—NUMBER ONE

for

SEPTEMBER

1931

New Permalloys

By G. W. ELMEN
Magnetics Research Engineer

WHEN the permalloys were introduced commercially into communication circuits, one of the alloys selected was that containing 78.5 per cent nickel and 21.5 per cent iron. This alloy was chosen for magnetic structures designed to operate at low field strengths, the region in which this composition is the most magnetic of the permalloy series. It is especially suited for direct current circuits where characteristics of the material other than the magnetic ones are of minor importance. For alternating-current circuits the electrical resistivity of the magnetic material should be high also, to cut down the loss caused by eddy currents, which are negligible in direct-current circuits. For alternating-current circuits, therefore, 78.5-permalloy — a designation indicating 78.5 per cent nickel and the rest iron—is less suited than other compositions of the permalloy series which, although less magnetic, have higher resistivity.

Another factor which must be given consideration in selecting a permalloy for commercial use is the special heat treatment required after the material has been fabricated into suitable shape. For most magnetic materials an ordinary anneal develops the desirable magnetic properties. A single heat treatment is also sufficient for a large part of the permalloy series, but 78.5-permalloy requires, in addition and subsequent to this anneal, a special heating at 600° C followed by rapid cooling. Since the magnetic properties of this composition depend largely on the rate of cooling, this step of the process must be held to fairly close limits to obtain a product with uniform characteristics. This special process naturally increases the cost of the finished core structures.

It was felt that the usefulness of the 78.5-permalloy could be increased if it were possible to raise its resistivity, and to modify its characteristics so that the heat treatment could be simplified. Work on magnetic alloys, therefore, was directed toward the development of an alloy which, while having substantially the same magnetic properties at low field

Fig. 1—Adding either chromium or molybdenum to permalloy with 78.5% nickel increases its resistivity

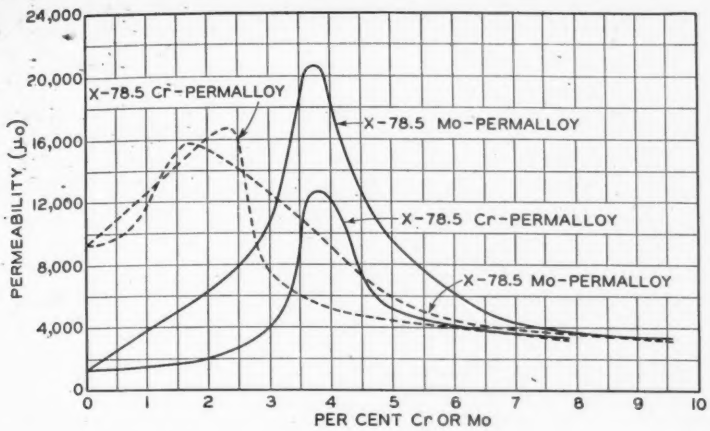


Fig. 2—Addition of chromium or molybdenum also tends to increase the initial permeability. The solid curves are for the annealed alloy and the dotted, for the quenched

erties. It was found also that the characteristics of the resulting alloys were so altered that for some of the most useful and interesting compositions a simple anneal sufficed to develop the desirable magnetic properties.

The effects of these metals may be illustrated by two series of ternary alloys each containing 78.5 per cent nickel but with varying amounts of either

strengths as the 78.5-permalloy, would have a higher resistivity, and require a simpler heat treatment.

A survey of the possible means by which the desired properties could be attained indicated that a modification of the composition by the alloying of other metals with the permalloys appeared to be the most promising. Our exploratory work, therefore, concerned itself with searching for a metal which would readily alloy with iron and nickel and which, when added in small quantities, would increase the resistivity of the alloy without affecting unfavorably the magnetic qualities. The most encouraging results were obtained with chromium and molybdenum. Both of these metals, when alloyed in small amounts with some of the permalloy compositions, improved materially both the resistivities and the magnetic prop-

chromium or molybdenum. To indicate the compositions of the various alloys, percentages are prefixed. Thus 3.8-78.5 molybdenum permalloy contains 3.8 per cent molybdenum, 78.5 per cent nickel and the rest iron.

The increase in resistivity caused by the addition of molybdenum or chromium is illustrated by Figure 1. Small percentages of either metal markedly affect the resistivity but the effect of chromium is the greater.

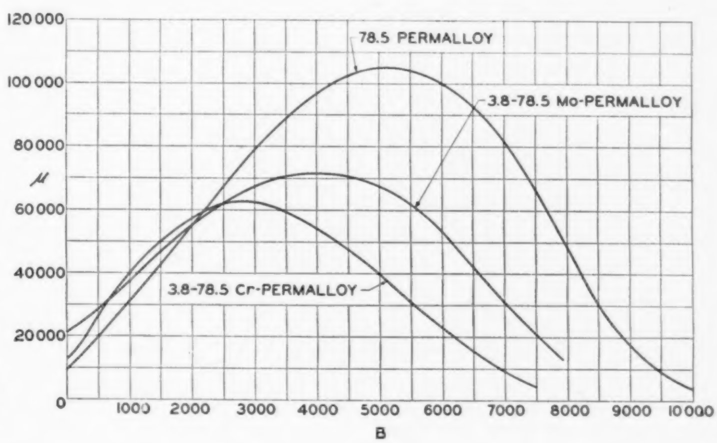


Fig. 3—The increase in permeability with the addition of 3.8% of molybdenum or chromium does not continue as the flux density is increased

With the addition of one per cent of this metal the resistivity is more than doubled. The increase in resistivity, although not so large with larger percentages, continues throughout the range of compositions shown.

To bring out the best magnetic qualities different heat treatments are required depending on the percentage of non-magnetic metal added. Typical differences can be illustrated by two heat treatments. For one the specimens were annealed by heating to 950° C and then cooled slowly, and for the other a similar anneal was followed by a reheating to 600° C and a subsequent rapid cooling in air. Alloys receiving the latter treatment are referred to as air quenched while those receiving the single treatment are designated as annealed.

An interesting and unexpected result of the studies made was the discovery that under some conditions the addition of small percentages of non-magnetic metals made the alloy more magnetic. This is illustrated by Figure 2 which shows the effect on initial permeability of various percentages of both chromium and molybdenum. The dotted curves are for air-quenched specimens and the solid curves for annealed. The value of permeability for zero per cent of the added metal is, of course, the initial permeability of straight 78.5-permalloy, and it will be noted that additions of small amounts of both chromium and molybdenum give higher values. Molybdenum has the greatest effect. For the annealed alloy, 3.8 per cent molybdenum gives an initial permeability of 21,000—the highest* initial permeability for the alloys investigated and more than double the permeability of air-quenched and about eighteen times that for annealed 78.5-permalloy. In both of these annealed specimens the highest initial permeability is obtained with 3.8 per cent of the added metal.

A comparison of these same alloys with permalloy at higher magnetizing forces is shown on Figure 3. For higher flux densities—above 2000—the permeabilities of both the molybdenum and chromium alloys are lower than 78.5-permalloy. The saturation values are also found to be lower.

The effect of temperature on the magnetic properties was also studied. Specimens of the alloys were slowly passed through a temperature cycle between -190° C and a temperature a few degrees higher than that at which the alloy becomes non-magnetic. Magnetic measurements at low flux density were made while the alloys were passing through

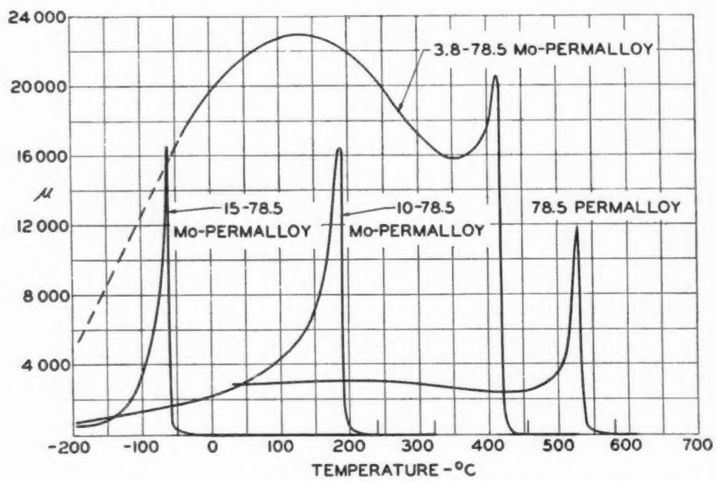


Fig. 4—Variations of permeability with temperature indicate that the Curie point is a function of composition

** P. P. Cioffi of these Laboratories has obtained an initial permeability of 35,000 for material of approximately this composition heat treated in hydrogen.*

this temperature cycle, and some of the results for molybdenum alloys are shown on Figure 4.

The temperature above which the material ceases to be magnetic is called the Curie point, and is indicated by a short vertical line on the temperature axis. It depends on composition only and is unaffected by heat treatment or field strength. For 78.5-permalloy the Curie point is 580° C, but is only 455° C when 3.8 per cent molybdenum is present and drops to 240° C for the alloy containing 15 per cent molybdenum. This variation is in accordance with the general rule that the addition of a non-magnetic element to a ferromagnetic material lowers the Curie point.

The curve for 3.8 per cent molybdenum differs distinctly from the others in having a region of high permeability that extends over a wide temperature range and includes ordinary room temperatures. Permalloys that have their high permeability developed by rapid cooling have similar characteristics when the cooling is so rapid that the structural changes that affect the magnetic properties of the alloy are not permitted to take place. The permeability temperature curve for rapidly-cooled 78.5-permalloy, for example, is very similar in shape to the curve for 3.8-78.5 molybdenum permalloy of Figure 4. For other permalloys containing 78.5 per cent nickel but less than 3.8 per cent molybdenum or chromium the highest permeabilities result from cooling at rates between those for annealing and air quenching. These results suggest that some of the non-magnetic metals when added in small amounts have an effect in developing magnetic properties similar to air quenching.

The curves of Figure 4 are for low flux densities. With curves for higher densities, the section of the curve on the low temperature side of the peak is higher, and the peaks disappear. When saturation is approached there is a continuous decrease in permeability with increase in temperature throughout the whole range up to the Curie point.

From the large number of alloys studied, a few have been developed for commercial use. The aim in selecting these alloys has been to limit their number to as great an extent as is consistent with the requirements for various types of apparatus in which a benefit could be obtained. One composition, for example, has been selected for cores of apparatus used in alternating-current circuits, such as transformers and retardation coils. Another composition is used for loading coils, and a third for the continuous loading of long submarine telegraph cables. The number of commercial alloys will, no doubt, continue to grow as requirements for apparatus to meet new and more severe conditions arise.

Four-Wire Telephone Circuits

By G. C. CRAWFORD
Toll Systems Development

ONE does not ordinarily think of a telephone circuit as consisting of more than a single pair of wires. This is, of course, the usual situation although with phantomed or carrier circuits not even the exclusive use of a single pair of wires is required. With very long loaded cable circuits, however, requiring many repeaters, it has been found that two pairs of wires provide the most satisfactory and economical arrangement from a transmission standpoint. Each pair of conductors of such a four-wire circuit carries conversation in one direction only, so that the repeaters are not connected through hybrid coils as they are for two-wire circuits* but are directly inserted in the line.

* RECORD, *August*, 1931, *p.* 579.

The arrangement is as shown in Figure 1. At each terminal an ordinary two-wire circuit is coupled to the four-wire transmission line through two transformers. Voice currents from subscriber "A", for example, pass into the terminating circuit T_1 where similar currents are induced in both halves of the four-wire circuit. None (ideally) pass to the network. Those induced in the east bound channel are attenuated by successive sections of line and amplified by the repeaters while those induced in the west bound channel are absorbed since the repeaters are unidirectional.

Arriving at the east terminating set, the east bound current divides. Half of the power goes to the listener at B and half to the network.

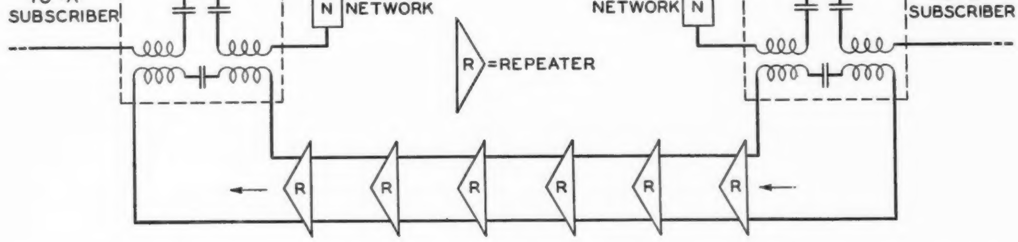


Fig. 1—With a four-wire circuit one pair of conductors carries the conversation in one direction and the other pair in the opposite direction

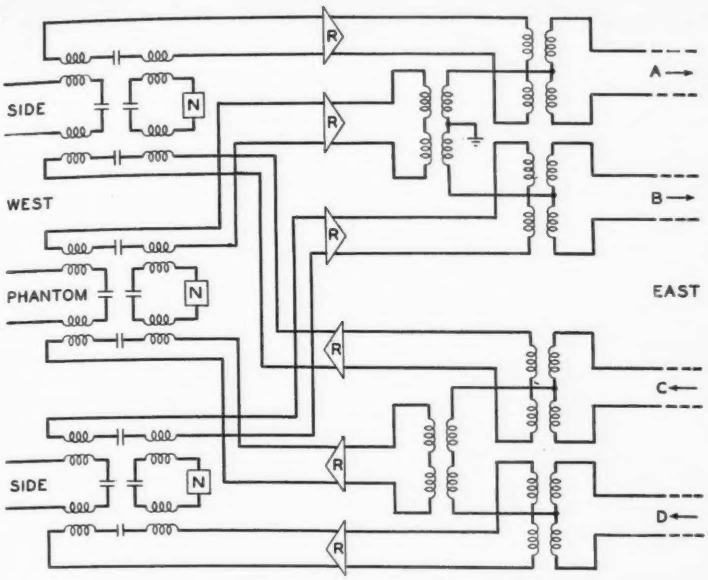


Fig. 2—Two quads supply three talking circuits—two side circuits and a phantom—and each quad carries conversations in only one direction

If the network perfectly balances the terminating line, no current will be induced in the lower or return channel. Because it is not practicable to secure a perfect balance, however, a small amount of current will be induced in the west channel and will be returned to the speaker as an echo.

Since it is only at the end of the line that an echo can be induced in this manner, a four-wire circuit has an obvious advantage over a two-wire circuit which has an equivalent balancing network, and thus the possibility of echo, at each repeater station. This is one of the reasons that make four-wire circuits more satisfactory for long lines where large numbers of repeaters are necessary.

Another of the advantages of four-wire circuits is that it is possible to keep the conductors which carry conversation in one direction separated from those which carry conversation in the other direction. This results in much less cross-talk coupling between circuit terminals than would otherwise exist. For a given limit of cross-talk at circuit terminals, therefore, it is permissible to allow greater loss between repeaters and a greater number of repeater sections than in the case of two-wire circuits where separation of opposite directional talking paths is not possible.

Wires in toll cables are not run in pairs but in quads: two pairs of wires twisted together. For reasons of economy cable circuits are always phantomed, and with four-wire circuits two quads are required to make three talking circuits—two side circuits and a phantom. The arrange-

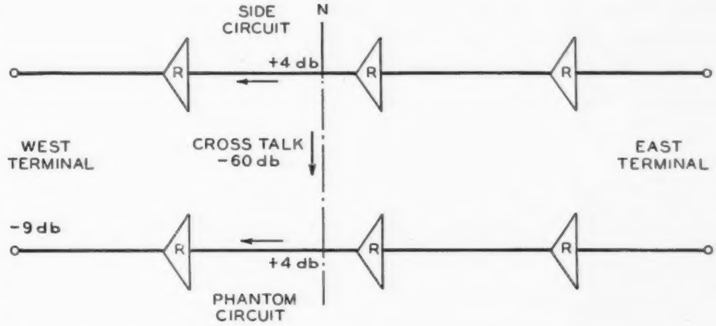


Fig. 3—With a four-wire circuit voice currents in the side and phantom circuits are flowing in the same direction and the cross-talk is the same number of db below the voice currents at all points

ment is shown in Figure 2 where pairs A and B form one quad and C and D, another. Connections are arranged so that one quad carries the three conversations in one direction and the other quad those in the opposite direction.

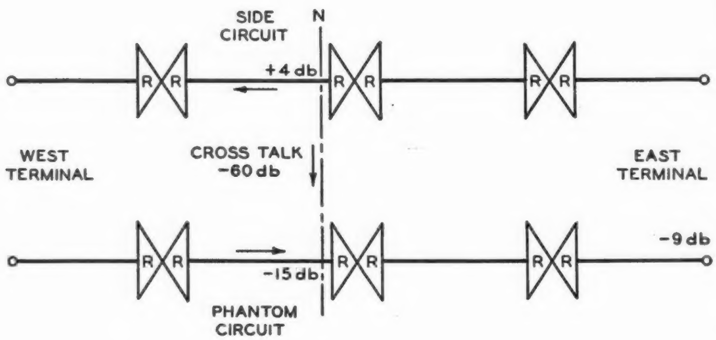


Fig. 4—With two-wire circuits, currents within the same quad may be flowing in opposite directions and as a result the received cross talk may be at a higher level relative to the voice currents at the end of the line than at the place where it was induced

With two-wire circuits there can be cross-talk between a side circuit transmitting conversation in one direction and the phantom of this side circuit transmitting conversation in the other direction. With four-wire circuits arranged as in Figure 2, the repeaters in one quad are all pointed in the same direction, and cross-talk from a side circuit into its phantom circuit can only appear at the end of the phantom circuit distant from the end of the side circuit where the disturbing subscriber is talking. Any cross-talk between channels, in the upper quad, for example, can not be transmitted back to the West subscriber because the repeaters are all pointed in the other direction. With this arrangement, the currents in one quad are all at about the same level at any one point. If cross-talk coupling exists at any point, a small percentage of the inducing current will appear in the disturbed circuit. The cross-talk current will be the same percentage of the voice current in the disturbed circuit since the currents in both circuits are at the same level. At the east end of the line the cross-talk current will be the same number of db below the voice current in the disturbed circuit as it was at the point of disturbance, since both currents are attenuated and amplified alike.

This situation is illustrated in Figure 3. At some point N in the circuit it will be assumed that the voice level in both side and phantom is +4 db and that the cross-talk is 60 db lower. The cross-talk induced in the phantom at this point, therefore, is at a level of —56 db (+4—60). Since the level of the voice current at the terminal is —9 db, there is a loss of 13 db between the point N and the terminal so that the received cross-talk will be at a level of —69 db (—56—13) which is also 60 db below the level of the received voice current.

In a two-wire circuit, on the other hand, the currents in a single quad, under the worst conditions, might be flowing in one direction in a side circuit and in the opposite direction in the phantom. Under these conditions the level in a disturbed circuit might be considerably below that in the disturbing circuit and a cross-talk current might be a much smaller number of db below the voice current in the

disturbed circuit than below that in the disturbing circuit. As a result, the cross-talk current will be a much smaller number of db below the voice current in the disturbed circuit at the end of the line than it would have been if the voice currents in the two circuits had been at the same level at the point where the cross-talk was induced.

Assume the conditions of Figure 4 where on one side of the repeater station (N) the voice currents in one of the side circuits, flowing from east to west, have just been amplified while those in the phantom, flowing from west to east, have just been attenuated by the section of line between this station and the next repeater to the west. Under these conditions assume that the level of the westbound current is +4 db, that the level of the eastbound current is —15 db, and that the cross-talk is 60 db below the level of the inducing current. The cross-talk induced in the phantom will thus be at a level of —56 db (+4—60). If the level of the received voice current is —9 db, there is an amplification of 6 db (—15 —(—9) between the point N and the end of the line. As a result the cross-talk at the end of the line will be at a level of —50 db (—56 +6) which is only 41 db below the level of the received voice current. In the case of the four-wire circuit, the same cross-talk coupling results in a cross-talk current 60 db below the level of the received voice current. The cross-talk current has, therefore, been amplified 19 db in comparison with the situation in the four-wire circuit.

This amplification of cross-talk will exist between four-wire talking paths of opposite directions but, as mentioned above, these paths can be separated sufficiently to keep the cross-talk currents at the circuit terminals within reasonable bounds. The method of segregating the quads for transmission in one direction from those for the other direction is shown in Figure 5.

The repeater employed for four-wire circuits, known as the 44-A-1, was designed about 1922. As shown in Figure 6 its circuit consists of two two-stage amplifiers—one for each side of the circuit. The attenuation introduced by the line varies with frequency in a manner that differs somewhat for various types of line. That for a 19 gauge H-44-25 line, the most common present type for four-wire circuits, is shown in Figure 7. Over a 50-mile repeater section, which has been found to be the most

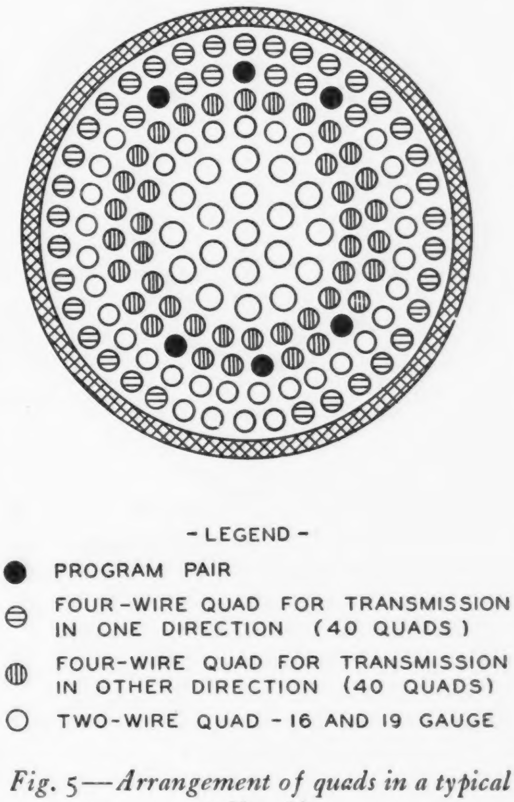


Fig. 5—Arrangement of quads in a typical toll cable

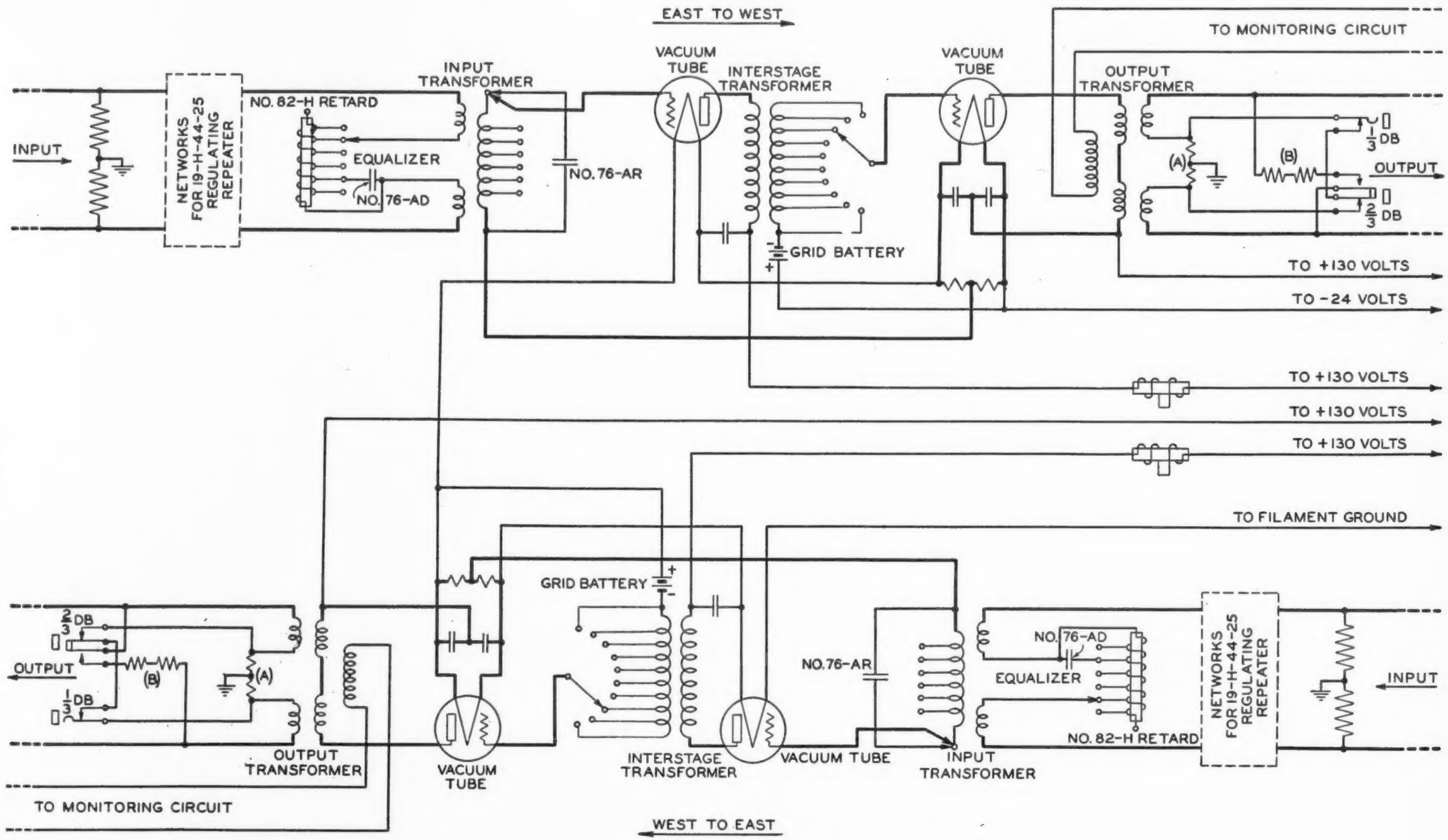


Fig. 6—Schematic diagram of 44-A-1 repeater

desirable spacing for repeaters in such cable circuits, the loss is about 24 db at 1000 cycles and decreases below this frequency and increases above it. The 44-A-1 repeater, therefore, is designed to give the necessary gain at 1000 cycles, and incorporates adjustable circuits by which the gain at frequencies above 1000 cycles may be regulated to conform to the characteristics of the circuit with which the repeater is being used.

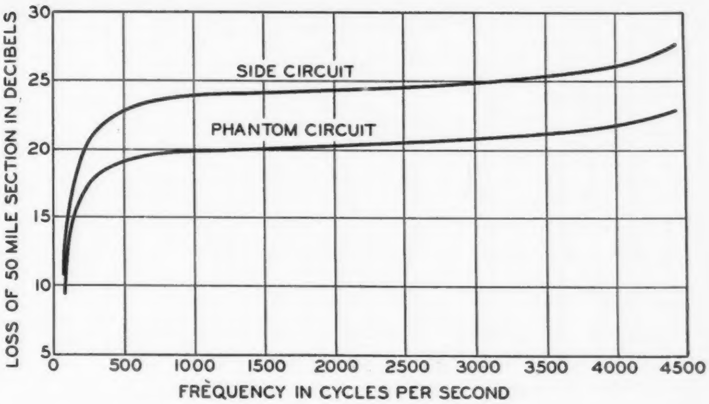


Fig. 7—Attenuation for an H-44-25 line at 55° F.

The gain at 1000 cycles, which is adjustable, may be controlled in three places. Approximately 5 db steps may be obtained from taps on the input transformer. Once the repeater has been adjusted it is not ordinarily necessary to change these connections. Finer gain adjustment is obtainable from taps on the interstage transformer. These connections may be changed by operating a switch, shown in the photograph of a repeater panel in Figure 8, and are in steps of approximately one db each. Still smaller steps, of either 1/3 or 2/3 db, may be obtained by inserting plugs in either of two jacks. In one case the resistance A is put in series with the output coil and in the other, the resistance B is connected across the output coil in addition.

The gain-frequency characteristic above 1000 cycles is controlled by taps on the 82-H retard coil by the 76-AD and 76-AR condensers. By this arrangement the characteristics above 1000 cycles may be made flat, or may be made to have a rising gain with frequency which, at 2200 cycles, may be as much as 8 db above the 1000 cycle gain.

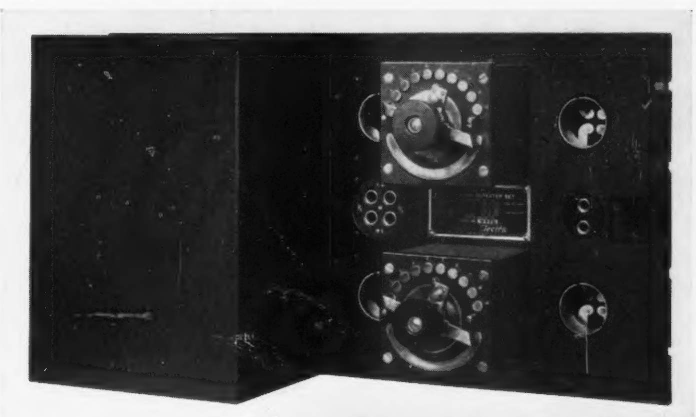


Fig. 8—A single panel of 44-A-1 repeater showing dials for gain adjustment

The characteristics below 1000 cycles are inherent in the repeater circuit and for H-174-63 circuits, a type of loading formerly used to a considerable extent, fit the characteristics of the line very well. To obtain the proper characteristics over this range for H-44-25 circuits, addi-

tional networks incorporated in the phantom repeating coils are employed.

The attenuation characteristics given in Figure 7 are for a conductor temperature of 55° F. At other temperatures the attenuation will differ from these values. At 1000 cycles, for example, the attenuation per mile for the cable circuit shown changes .055 db with a 54° change in temperature either above or below the base temperature. The change in attenuation with temperature, however, is not the same for all frequencies: the slope of the frequency-attenuation curve is shifted as well. To modify the gain to conform to the complex change in attenuation due to temperature, regulating repeaters are employed. These are essentially the same as the other repeaters except that provision is made to change the gain automatically to compensate for changes in temperature. The method by which this is accomplished has already been described in the RECORD.* A potentiometer network, shown in dotted lines in Figure 6, is connected across the input side of the regulating repeater and the input to the amplifier is automatically switched to different points on the potentiometer depending on the temperature.

A regulator section is the unit for four-wire circuits. Any number of such sections, each of which is built up of one or more repeater sections, may be connected together up to the maximum allowable length of circuit, as limited by various transmission considerations. The objectionable effect of echoes increases with the time interval between a spoken sound and the return of the echo, and this time, of course, varies with the length of the circuit. For distances great enough to give objectionable echoes, it is necessary to employ echo suppressors. With 19 gauge cable circuits, where the usual H-44-25 loading is employed, echo suppressors are usually employed when the length exceeds three or four hundred miles.

* RECORD, *January*, 1929, *p.* 183

Non-Ferrous Alloys

By L. E. ABBOTT
Materials Development

A LARGE quantity of non-ferrous alloys is used in the manufacture of telephone apparatus. Constant study of new developments in this class of alloys is made to discover metals which might constitute improvements over those in present use. Substantial savings in manufacturing and maintenance costs, as well as more efficient service, may be effected through the use of new alloys having superior physical, electrical, or corrosion-resistant properties. There is also the possibility that specific properties of newly developed alloys might be used with advantage in the design of new telephone apparatus.

Extensive work is done in our own Laboratories on the development of new alloys. In addition there are several means by which we keep in touch with developments on the outside. Information on new alloys is acquired partly by scanning trade publications but principally through the activities of Laboratories men in technical societies, such as the American Institute of Mining and Metallurgical Engineers, the American Society for Testing Materials and the American Society for Steel Treating. Frequently joint investigation of the alloy is carried on by the Laboratories and the manufacturer. Often samples of new alloys are sent in by outside individuals or concerns asking that the Laboratories investigate them for possible application in the telephone plant.

The tests made upon these numerous alloys vary according to the use for which the alloys are intended. The ability of an alloy to withstand heavy loads either of tension or compression, the amount which the material elongates under load, its hardness and its ability to regain its original form after having been elongated are all important properties for which precise values must be obtained. Numerous types of testing equipment, giving a high degree of accuracy, are used in the evaluation of these properties. Two of these machines, the Rockwell hardness tester and the Amsler hydraulic testing machine, are shown in the accompanying pictures. The results of such tests give an excellent picture of the usefulness of the material.

The alloys received for test may generally be classified as belonging to one of the following metallurgical groups, namely, dispersion-hardened, solid-solution and sintered alloys. Each of these groups represents a distinct metallurgical process for the production of alloys which have specific properties and uses.

The increasing application within recent years of dispersion-hardening has given great impetus to the development of non-ferrous metals. The useful properties of the alloy are greatly improved by a heat-treating

process which is similar to that by which steel is hardened. As metals are all crystalline, failure under load is attributed to slip along certain weak planes of the crystals. When an alloy is dispersion-hardened, small, hard particles are distributed along these weak planes in the crystals and act as "keys" or brakes. As a consequence the likelihood of failure by the occurrence of slip along these crystal planes is much reduced. By varying quenching conditions and temperature and duration of aging, large variations in the physical properties of the finished product may be obtained. Two examples of commercially available dispersion-hardened alloys are Duralumin, the discovery of which led to the development of dispersion-hardening as a process, and Tempaloy, a hardened copper alloy.

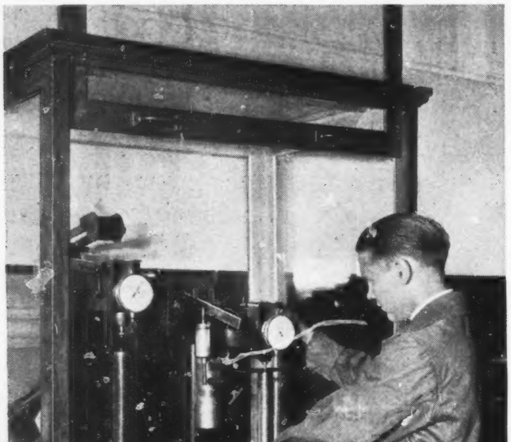


Fig. 1—The chief test used in the Laboratories for determining the hardness of sheet metal and apparatus parts is the Rockwell Hardness Test. Measurement is made of the penetration into a material of a diamond cone or small steel ball under a known load. W. J. Padgett is operating the tester

Duralumin is aluminum to which has been added small amounts of other elements, usually copper, magnesium, silicon and manganese, which enable it to be hardened and strengthened far beyond its normal strength through use of dispersion-hardening heat treatments. The material is used extensively for telephone transmitter diaphragms, for radio broadcasting receiver and transmitter diaphragms and as ribbon in the light valve for sound recording. Its uses are increasing rapidly, for it combines strength with light weight, and can be formed easily into any desired shape before being hardened by dispersion methods.

Copper to which nickel and silicon have been added is susceptible to dispersion-hardening treatment. Tempaloy is the commercial name for this alloy. As in the heat treatment of steel, the advantages gained by dispersion-hardening copper are increased strength, better resistance to reversed flexural stress (fatigue resistance), and similar improvement in other physical properties.

Another and more numerous class of non-ferrous alloys consists of the solid-solution alloys. This type of alloy is formed by a solution of the metals composing it; that is, one metal dissolves in the other in much the same way as two or more liquids would combine. Alloys formed by solution have physical properties widely different from those of the metals used as constituents. Marked changes in physical properties, moreover, may be obtained by varying the proportions of the constituent metals. These alloys are not susceptible to hardening by heat treatment. In-

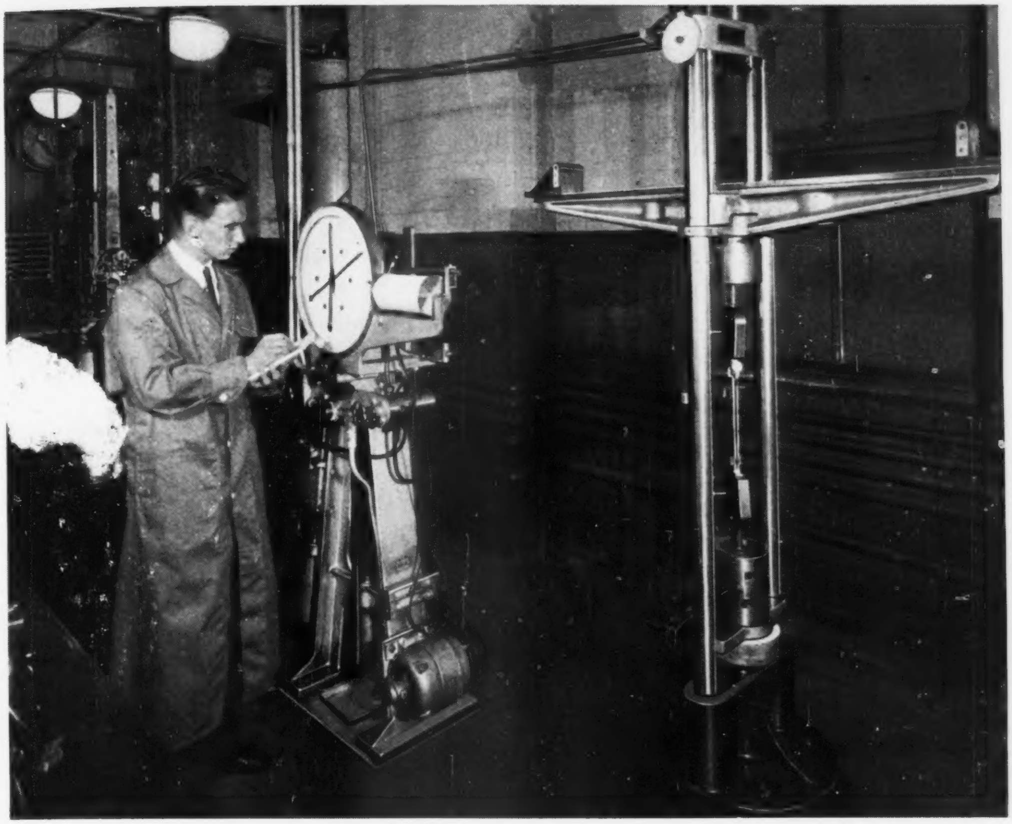


Fig. 2—E. A. Bacquet recording proportional-limit and tensile-strength data for a sheet metal specimen under test in an Amsler hydraulic testing machine

creased hardness and strength is provided by cold rolling or working.

A prominent alloy of this class is Everdur, composed of copper given increased strength and hardness by additions of manganese and silicon. It possesses high fatigue resistance, does not season-crack*, resists atmospheric and salt-water corrosion as well as cold hydrochloric and sulphuric acid attack. At the present time it is undergoing thorough investigation for possible uses in telephony.

Solid-solution alloys using nickel as one of the constituents are widely used. Small percentages of nickel seem to have a beneficial effect on almost any alloy with which it forms a solid solution and consequently a great number of commercial alloys have some nickel in them. Monel metal is an example of nickel alloy used in telephone work. In addition, more distinctly in the ferrous class, there are platinite and the well-known permalloy developed in these Laboratories.

Monel metal contains approximately 67 per cent nickel, 28 per cent copper, and 5 per cent of minor constituents, chiefly iron and manganese. It resembles nickel in color, has high tensile strength, resists corrosion, oxidation and erosion. It also retains its strength at high temperatures to a greater extent than most alloys. It has a modulus of elasticity of 25,000,000 pounds per square inch, a value which makes it suitable as a spring

* Bell Laboratories Record, *October,* 1929, *p.* 77

material in certain special cases.

An alloy with the same ratio of copper and nickel present as monel metal, but containing in addition about 3 per cent of aluminum and 0.25 per cent carbon is known as 'K' monel metal. By virtue of the addition of the aluminum and carbon the alloy is no longer a solid-solution alloy and is capable of being heat-treated by which wide variation in its physical properties may be obtained. At high temperatures this alloy holds its strength as well as a number of alloy steels.

Tungsten-carbide alloy, a recent and important metallurgical development, will undoubtedly have important uses in telephone work. It is representative of a group of non-ferrous alloys formed by heating and compressing metallic powders, a process known as sintering. This particular alloy consists of particles of tungsten carbide cemented together with cobalt by a special process, giving a material of extreme hardness just below that of the diamond. Preparation of this type of alloy constitutes the latest step forward in metallurgical methods. Tungsten carbide in the form of a fine powder is mixed with metallic cobalt, ball-milled so that the particles of carbide compound become coated with cobalt, and then pressed into the desired shape and size. The material is then partly sintered by heating to a low temperature and can be formed by a steel tool at this stage without breaking. The cementing process is completed in an electric furnace with a hydrogen atmosphere using a very high temperature.

Its uses thus far have been limited to manufacture of wire-drawing dies and tool tips for high-speed work where high working temperatures must be withstood. Its main service in telephone work doubtlessly will be in the added strength given to tools for machining apparatus parts. It may prove the means whereby a number of alloys which previously have been regarded as not of practical value because of the difficulty of machining may be made available for telephone apparatus.

NEWS AND PICTURES

of the

MONTH

Stenotype services of the Transcription Department—Miss Irene Leonard taking dictation on the stenotype machine from R. A. Devereux

General News Items

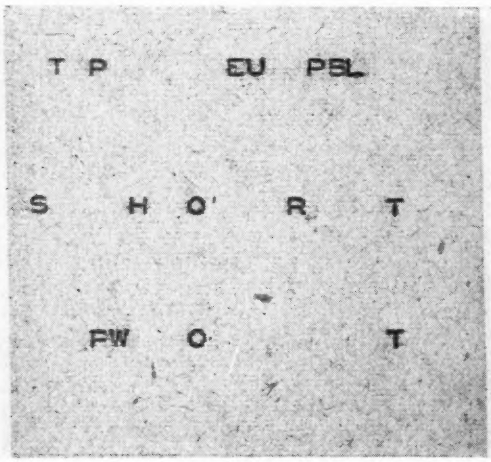
MANY ADVANTAGES INHERENT IN STENOTYPE SERVICE

Perhaps the nimblest fingers of any in the Laboratories are those of the stenotypists in the Transcription Department. With one stroke they can write "had you been" or a similar phrase, and write it within only a small fraction of a second more time than it takes to speak it. The method they use is stenotypy, a system of recording speech in plain English letters by means of a small machine weighing 4½ pounds, called the stenotype.

The stenotype keyboard is divided into three groups of letters. At the left, the first four pairs of keys compose the group known as the initial consonants. The group of four keys in the middle of the keyboard, placed slightly below the consonant keys, represents the vowels. At the right of the keyboard, five pairs of keys constitute the group used for final consonants. As there are only eight consonants on the left side and ten of the final consonants, combinations are used to represent the consonants not on the keyboard. The word "final," for example, is written:

TP EU PBL

The combination TP is f; the vowel i, which is the only one not included on the vowel keyboard, is indicated by EU; n by PB; and then the final l. As the word is easily recognizable without it, the second vowel a is omitted.



The words "final," "short" and "bought" recorded on stenotype tape

The rapidity of typing by the stenotype process is made possible by the limited number of keys which are operated by the several fingers of both hands with one quick, rapid stroke.

The word "short" is written out in full, because all its letters are on the machine. Words are also written as they sound. For instance, "bought" is written as if it were spelled "bot"; thus

PW O T

The combination PW represents the initial consonant b which is not on the keyboard.

The keys of the stenotype always strike in the same position on the paper, the initial consonant at the left on the tape, the vowels in the center, and the final consonants at the right. The stenotypist may depress keys in any or all of the groups at one time, so that a word, or a phrase containing several words, may be written at each stroke. When the keys are struck, the paper automatically feeds forward for a new line.

Stenotypy has a number of advantages over stenography. It is easier to learn, since the characters are ordinary English letters, not hooks and curves, dots and dashes; it is more accurate and legible; and it is faster. A good stenotypist writes as fast as the average person talks. The fact that a stenotypist does not have to glue her eyes to a note book, but can watch the person dictating as he talks, tends to make her work more accurate.

Stenotype notes, moreover, may be transcribed by persons other than the stenotypist who originally took them. This makes for greater flexibility in handling the dictated work of a large department such as our Transcription Department. A stenotypist, for instance, after taking notes for an hour or two at a conference, may send them to a transcriber, and continue on with her work. By the time the conference is over, probably half or more of the notes may be already in typewritten

form. Or if a man should dictate a large number of letters, say fifteen or twenty, which he is anxious to have typed and returned to him within a short time, the work of typing may be speeded up by distributing the notes among five or six transcribers.

At the present time the Transcription Department, according to Miss Isabel H. Benedict who is in charge, has twenty-four stenotypists and eighteen transcribers. All of the transcribers were taught to read stenotype notes by Miss Alice Wolfe, head stenotypist. Nine of the eighteen transcribers are now studying to become full-fledged stenotypists.

H. E. SHREEVE TO DEPART FOR C. C. I. MEETING

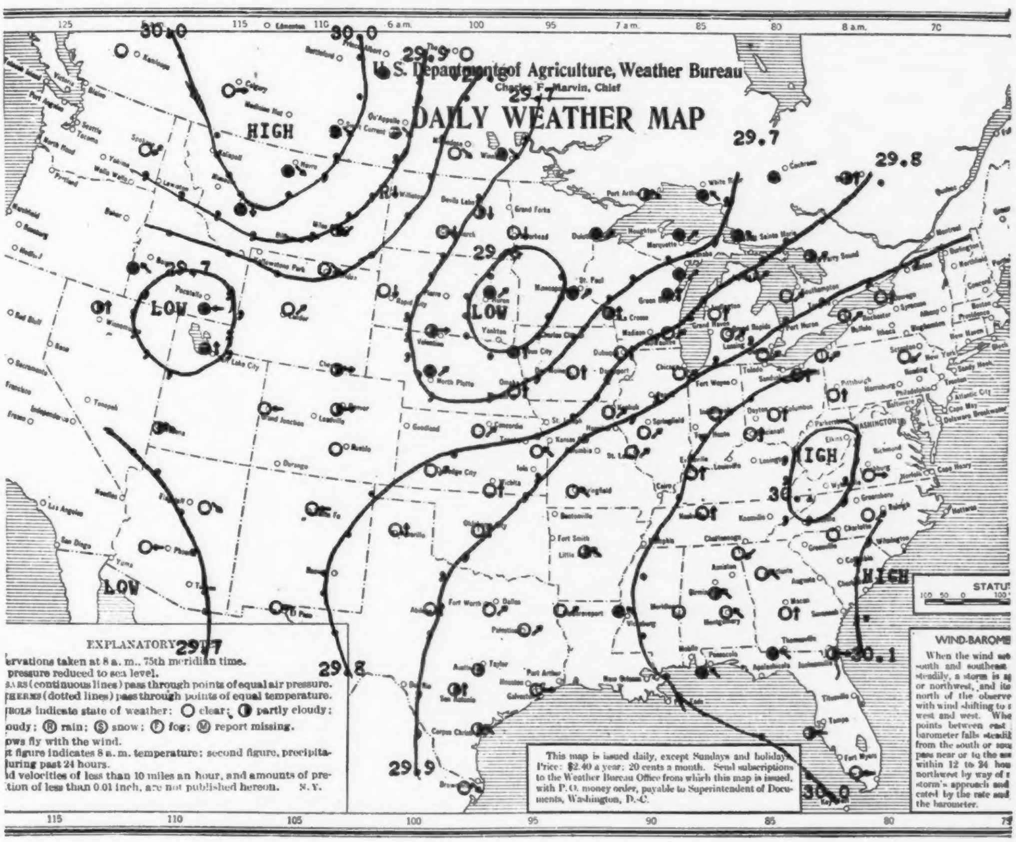
H. E. Shreeve, Technical Representative of the American Telephone and Telegraph Company and the Laboratories in Europe, is at present at the Headquarters Building of the A. T. & T. Co. He expects to leave for Europe about September 7 to attend the Paris meeting of the Comité Consultatif International des Communications Téléphoniques à Grande Distance.

WEATHER MAPS TRANSMITTED BY TELETYPEWRITER SYSTEM

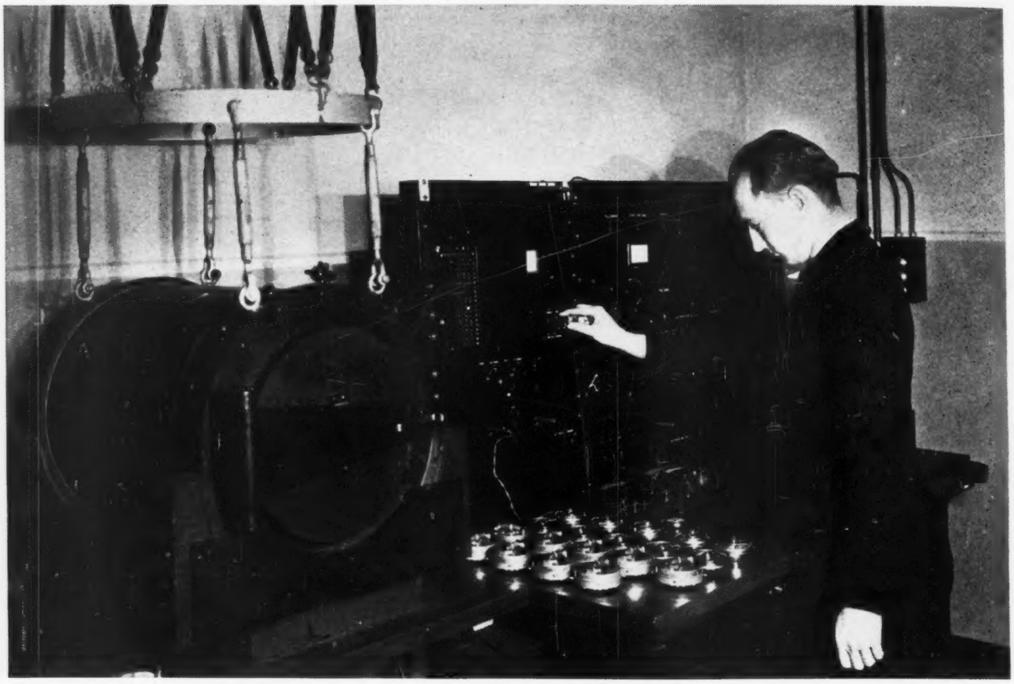
The Aeronautics Branch of the Department of Commerce and the Long Lines Department are now experimenting with the transmission of weather maps to airway stations by means of the teletypewriter system. The service will supplement the written weather reports now sent over the teletypewriter circuits on half hour and hourly schedules.

A page-type printer is employed into which an outline map of the United States is inserted. To indicate the lines of equal barometric pressure, known as isobars, series of periods and commas are transmitted. After the page is removed from the machine, lines are drawn through these marks as shown on the accompanying illustration. The barometric pressure of each isobar as well as the words "High" and "Low" are also printed by the machine.

To convey additional information, type



Weather Map on which essential information is transmitted over teletypewriter system



Testing a 600-A microphone for carbon noise. A certain amount of gas is contained in the surface pores of the carbon granules and when the granules are heated by the passage of the current the gas is driven off and produces non-periodic changes in resistance which, in turn, cause carbon noise. H. G. Schmitt of the Research Department is performing the test. Volume-efficiency is also determined during this test

castings of weather symbols have been made and fitted on the machines. One kind of dots indicating cloudy weather, another kind of dots denoting partly cloudy conditions, arrows showing wind directions, and symbols warning of thunder storms are all printed on the maps. Because of the simplicity of this method, data for the maps can be transmitted within fifteen minutes to each station receiving the service. F. R. McMurry, in charge of Printing Telegraph Apparatus, assisted the Teletype Corporation in arranging for the special type symbols fitted on the machines.

RADIO PROGRAMS SPONSORED BY BELL SYSTEM COMPANIES

Beginning September 13, four adjoining Bell System Companies—New York, New Jersey, Pennsylvania, and C. & P.—will cooperate to furnish a high quality musical program to be broadcast on Sunday nights. The entertainment, to be provided by a symphony orchestra assisted by a chorus of 16 voices with occasional soloists, will be of a half hour's duration. On September 13 and 20 the program will be broadcast from 8:30 to 9:00 P.M. Eastern Daylight Time: thereafter the program is scheduled for the same period Eastern Standard Time.

The stations which will broadcast the programs are as follows: WABC, New York; WCAU, Philadelphia; WCAO, Baltimore; WMAL, Washington; WOKO, Albany; WFBL, Syracuse; WGR, Buffalo.

In view of the Laboratories' large contributions to the apparatus and technique of radio broadcasting and the Bell System's present substantial interest in the wire hook-ups used today, Laboratories members will be interested in following these programs. The present series of broadcasts are designed to promote the use of long distance calls and it is hoped that Bell System employees engaged in sales activities will find the radio programs of considerable assistance in promoting long distance sales among their friends.

Departmental News

RESEARCH

Transmission Instruments

H. A. Larlee visited the Northern Electric Company at Montreal to aid in the inauguration of manufacturing operations on the station handset.

R. E. Drake completed twenty years in the Bell System on August 1.

Chemical Research

After the meeting of the American Society for Testing Materials at Chicago, R. M. Burns, C. L. Hippensteel, and R. B. Mears visited Hawthorne to discuss problems on finishes. E. E. Schumacher and J. H. Ingmanson also attended the A. S. T. M. meeting. At Hawthorne Mr. Schumacher later engaged in base-metal contact and cable-sheath studies, and Mr. Ingmanson conferred on problems of asphalt and rubber.

A paper, *Potentiometric Titration in Non-aqueous Solutions*, by B. L. Clarke, L. A. Wooten and K. G. Compton was published July 15th in the Analytical Edition of Industrial and Engineering Chemistry.

V. J. Albano with I. C. Shafer, Jr., of the Outside Plant Department, made insulation resistance measurements on experimental underground drop wire at the soil corrosion test plot in Forked River.

A visit to the manufacturing plant of the National India Rubber Company situated at Bristol, Rhode Island, was made by A. R. Kemp and J. H. Ingmanson.

An article on surface leakage of pyrex glass, written by W. A. Yager and S. O. Morgan, is published in the July issue of the Journal of Physical Chemistry.

Electro-Optical Research

Herbert E. Ives has a paper on *The Projection of Parallax Panoramagrams*, published in the Journal of the Optical Society of America for July.

Transmission Research

J. W. Foley completed twenty years in the Bell System on August 7.

Acoustical Research

H. Fletcher attended a Board meeting of the American Association to Promote the Teaching of Speech to the Deaf held at Johns Hopkins, Baltimore.

On his return from Los Angeles W. B. Snow assisted Dr. E. Jacobson at the University of Chicago in making measurements of electrical currents in human muscles. Dr. Jacobson is planning a treatise on neuromuscular reactions and is using in the compilation of his data electrical measuring equipment provided by the Laboratories.

Radio and Vacuum Tube

E. J. Sterba is the author of the paper, *Theoretical and Practical Aspects of Directional Transmitting Systems*, appearing in the July issue of the Proceedings of the Institute of Radio Engineers.

In the Review of Scientific Instruments for July, E. K. Jaycox and H. W. Weinhart describe a new ionization manometer which they are using in their work. An abbreviated description of this device, written by Mr. Jaycox and entitled *Measuring One-Trillionth of an Atmosphere*, will appear in an early issue of the Record.

Submarine Cable

G. W. Elmen on August 30 completed twenty-five years in the Bell System.

Practically all of his association with the Western Electric Company and Laboratories has been devoted to magnetic materials and their uses. He is celebrated for his work on permalloy, one of the most significant developments in the field of magnetic alloys. A decade or more ago when the communication industry felt that it would be desirable to obtain a material with magnetic qualities superior to the iron and steel then in use, it was this iron and nickel alloy, developed after several years of painstaking and organized research, that proved the solution to the problem. In addition to its telephone uses, permalloy in the form of wire or thin tape wound around the copper conductor of an undersea cable, provid-

ing "continuous loading" has increased the message-carrying capacity of transoceanic telegraph cable five to six times.

Mr. Elmen's earlier researches in magnetic materials resulted in magnetic dust for loading coils. His latest work, as a collateral development from his investigations of permalloy, produced iron-nickel-cobalt alloys known as perminvars which have remarkable magnetic properties. Some of his latest developments are described in an article in this issue of the RECORD.

For his work on magnetic materials Mr. Elmen has been honored by awards of the John Scott Medal by Philadelphia and the Elliott Cresson Medal by the Franklin Institute.

TRANSVERSE Barkhausen effect in iron is described by R. M. Bozorth and J. F. Dillinger in the Physical Review, July 1. The article describes the continuation of their studies of the Barkhausen effect.

PATENT

DURING JULY the following members of the Patent Department made visits to Washington in connection with patent matters: G. H. Heydt; I. MacDonald; O. E. Rasmussen; J. W. Schmied.

PATENT MATTERS relating to the developments of the Laboratories in Sound Pictures are handled by G. H. Heydt. Reporting to him are W. L. Dawson, H. W. MacDougall and J. F. McEneany. Mr. Heydt is a graduate of Lafayette and has been a member of the Laboratories since 1915. He has taken a prominent part in activities of Bell Laboratories Club and for two years was department representative for the Patent Inspection group.

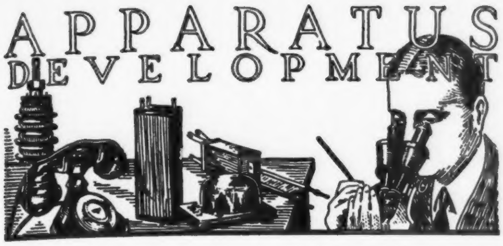
G. H. Heydt

FEW PERSONS, looking at Philip Rossi, would guess that his service with the Western Electric Company and Laboratories extends to forty years. The erectness of his bearing, the quick, alert flash of his eye, bespeak a man whose age is even less than the number of years Mr. Rossi has been associated with telephone work. But the records disclose that he became a member of the Western Electric Company in the old Thames Street factory on August 1, 1891. He had emigrated from Italy three years previous after graduating from High School and Agricultural College. He was a craftsman on stained glass work before coming with the Western Company.

For a number of years he worked on the manufacture of parts for transmitters. During this period he was engaged on outside studies of drafting and in 1903 he was assigned to the drafting section of the Apparatus Design Department. Ten years later he became a member of the Patent Department. His work consists of making the drawings of the various types of apparatus for which patents are applied at Washington.

Philip Rossi

A strong believer of cultivating hobbies, Mr. Rossi has made the study of music and voice his particular hobby. Years ago he was much sought after to sing at Engineering Club entertainments, but he has since given this up to devote his time to vocal instruction. When it becomes necessary to relinquish his active duties, he states that he would like nothing better than to teach a few selected pupils the intricacies of voice, and produce—who knows—another Caruso or Bori.



SPECIAL PRODUCTS

H. M. STOLLER visited Boston to discuss motors for sound picture projectors with the Holtzer-Cabot Company.

THE LABORATORIES' FORD airplane was used on a flight from Newark to Washington and return during which the Bureau of Standards visual course indicator and Western Electric two-way radio telephone equipment was demonstrated to the following interested persons: Dr. C. B. Jolliffe, Chief Engineer of the Federal Radio Commission, Mr. Thorp Hiscock, Commercial Engineer of United Air Transport, Mr. Paul Goldsborough, Vice President of Aeronautical Radio, Inc. and Mr. L. R. Manning of the Century Lines. Messrs. H. E. Young and H. N. Willets of the Western Electric Company also made the trip. The demonstration was conducted by D. K. Martin and D. B. McKey. A. R. Brooks and P. D. Lucas piloted the plane with R. J. Zilch as mechanic.

A SURVEY preparatory to the installation of a one-kilowatt radio - telephone broadcasting equipment for the Congress Square Hotel Company of Portland, Maine, was made at Manchester, New Hampshire, by H. S. Price.

A VISIT to the plant of the American Airplane and Engine Company at Farmingdale, Long Island, was made by D. K. Martin, W. A. Woods, P. S. March, D. B. McKey and A. R. Brooks, to inspect the first of a new type of commercial airplane designed to include two-way radio telephone equipment as an integral part of the construction of the plane.

TELEPHONE APPARATUS

H. T. WILHELM visited Philadelphia to inspect an impedance bridge and inductance standards under construction for the Laboratories.

A VISIT to the Utica Drop Forge and Tool Company, Utica, New York, was made by O. C. Eliason to inspect the manufacture of a special type of tool for Bell System use. He was accompanied by W. F. Johnson of the Western Electric Company.

B. O. TEMPLETON visited the plant of the Gray Telephone Pay Station Company at Hartford, Connecticut to confer on manufacturing details of coin collectors.

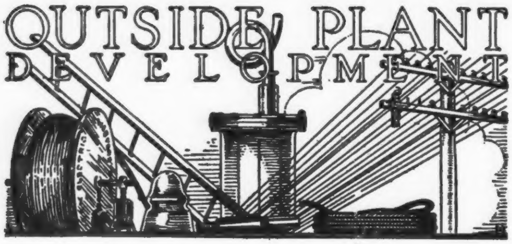
A. H. REIBER of the Teletype Corporation visited F. R. McMurry to discuss printing telegraph apparatus.

F. C. KUCH visited Albany and Philadelphia in connection with a trial installation of chromium-plated relays.

SHORT-CIRCUITING relay protectors were examined by J. D. Tebo in a recent visit to Martinsburg, West Virginia.

R. L. ELLIOTT of the Northern Electric Company visited the Laboratories for conferences with J. N. Reynolds, E. C. Mueller, and also H. A. Larlee of the Research Department and D. A. Quarles of the Outside Plant Department in connection with miscellaneous apparatus problems.

The small perforations in television scanning discs are cleaned by this specially-devised brush consisting of two strands of horse hair. The hands are those of A. L. Johnsrud



D. A. Quarles visited Professor R. H. Sherlock at Ann Arbor to discuss studies conducted by the University of Michigan on the storm loading of pole lines.

J. G. Brearley at Scranton observed the installation of cable with a new type of sheath.

W. Babington visited the Evans Wallower Zinc Company at East St. Louis to witness electrogalvanizing and the electrolytic production of zinc.

A field trial of recently developed methods and apparatus for reducing capacitance unbalances in toll cable was attended by R. C. Dehmel at Syracuse. He also visited the Simplex Cable Company at Boston to discuss the manufacture of leads for the 4-A test set.

Several test sections of one of the Allentown-Reading cables were inspected for possible evidences of sheath deterioration by J. A. Carr and G. B. Hall accompanied by representatives of the A. T. & T. Company. Messrs. Carr and Hall also visited New Haven in connection with a similar study of small sized cable of the Southern New England Telephone Company.

S. C. Cawthorn was twenty years a member of the Bell System on August 14.

INSPECTION ENGINEERING

A. G. Dalton visited Cleveland to attend with W. E. Whitworth, Field Engineer in that territory, the inaugural Field Review of Engineering Complaints with Long Lines Division No. 6 of the American Telephone and Telegraph Company.

During the latter part of July, L. E. Gaige, Field Engineer, Detroit, made field studies for a quality survey of C-4 Carrier Telephone Equipment in several Michigan cities, including Grand Rapids, Houghton, Ironwood, Marquette, Petosky and Traverse City.

L. G. Hoyt visited the warehouse of Electrical Research Products Incorporated, Chicago, to discuss current problems.

H. W. Nylund, Field Engineer, San Francisco, has been in Calusa, California, in connection with a selector supervisory system of Laboratories design installed in the plant of the Pacific Gas and Electric Company.

Recent visits to the Laboratories were made by J. H. Shepard, Field Engineer, Atlanta; A. J. Boesch, Field Engineer, Philadelphia; and W. E. Whitworth, Field Engineer, Cleveland, to confer on current field engineering matters.

On August 17 C. A. Johnson, formerly Field Engineer, Chicago, was appointed Field Engineer, New York No. 2.

STAFF

J. S. Hartnett has been appointed a member of the Programme Committee of the Young Men's Board of Trade, formerly known as the New York Junior Board of Trade.

F. Haese recently attended the convention of the Photographers' International Association at Sandusky, Ohio.

William Frees on August 26 completed twenty years of service in the Bell System.

A service pin of five stars denoting twenty-five years of service was awarded to George Rupp on August 29.

Mr. Rupp is foreman of the pipe-fitters and masons in the Building Service Department. For a number of years as a pipe-fitter he was Bill Calmar's right-hand man and in 1919 took Calmar's place as head of the pipe-fitters when the latter assumed charge of the Building Service Department. More recently the work of the masons was placed under his charge.

George Rupp

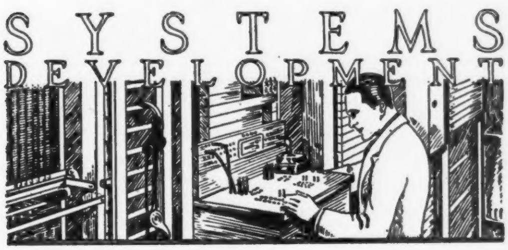
The thirtieth anniversary of Charles Westerburg's association with the Western Electric and Laboratories occurred on August 20. His first work was in the protector assem-

bly department of the Western Electric Company. In 1905 he transferred to the carbon button and repair department. He worked on transmitters, receivers and transmitter arms as a member of this department. When the manufacturing activities carried on in New York

Charles Westerburg

were moved to Hawthorne he became a member of the Model Shop.

Mr. Westerburg is now working in the coil division of the Development Shop impregnating, potting and assembling coils used in the development of apparatus. He is a member of the Edward J. Hall Chapter of the Telephone Pioneers of America.



Equipment Development

A trip to New Haven was made by R. A. Lautier for a trial installation of a new instructor's set.

In connection with the installation of a teletypewriter PBX switchboard system for the State Police, R. B. Simon was in Albany and E. A. Kuenzler visited Oneida, Sidney and Batavia in New York State.

Dial Equipment Development

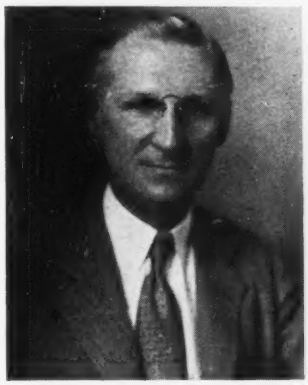
E. J. Kane has been in Hawthorne discussing problems of merchandising and manufacturing on the 370-type dial offices which have recently been developed for small isolated communities.

On August 22, C. D. Lindridge completed twenty-five years in the Bell System. For a year in 1906-1907 he was in the Plant Department of the New York Telephone Company inspecting central office equipment and then became associated with the former Providence Telephone Company where he was engaged on equipment and traffic engineering.

In 1917 Mr. Lindridge became a member of the 401st Telegraph Battalion, recruited from New England telephone men, and served at Camp Devens and Leon Springs, Texas. During the closing months of the war he was made a commissioned officer and assigned to the Chief Signal Officer's office at Washington.

He came with the Laboratories after being mustered out of service in 1919 and worked nearly a year on repeater development. Following this, he was assigned to carrier telephony, then in the early stages of its development.

Except for an interlude from 1923 to 1925 when he was engaged on equipment develop-



C. D. Lindridge

ment for toll switchboards, Mr. Lindridge has been engaged entirely on carrier work. He has had a part in the development of the Type "C" system and carrier pilot channel equipment.

R. D. De Kay was in Chicago to observe tests on QD-15 ringing machines. These machines are improved inverted rotary converters designed to supply ringing current in small telephone offices and private branch exchanges.

Power Development

R. L. Lunsford discussed general power questions with engineers at Hawthorne.

F. F. Siebert and H. M. Spicer were in Schenectady to test motor-driven alternator sets to be used with hotel public-address and music-reproduction sets.

V. T. Callahan on a recent trip to Buffalo was concerned with improved fuel pumps, silencers and flexible exhaust sections for use with gasoline engines in reserve power plants.

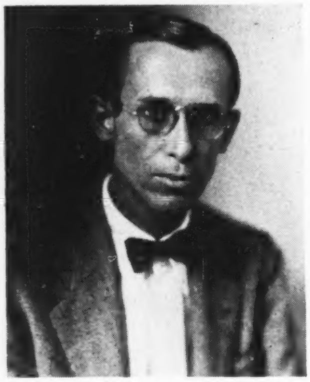
J. H. Sole was in Fort Wayne on problems of centrifugal voltage regulators and toll lighting transformers.

Power equipment associated with the 44-B repeater on trial installation at Greensboro, North Carolina, was inspected by R. P. Jutson.

Local Central Office

H. G. W. Brown's career in the telephone industry, dating from the time when he entered the employ of the New England Telephone and Telegraph Company as a switchboard operator, extended to twenty-five years on August 1. From operating Mr. Brown advanced to general maintenance work in the Springfield area of the New England Company. He worked on central office, PBX, line and substation maintenance which gave him an extensive knowledge of manual systems before coming with the Laboratories in 1920.

As a member of the Laboratories' technical staff he was assigned to the manual systems development where he specialized in the standardization of signalling and alarm circuits, and later was occupied entirely with standardization activities. Since 1929 he has been engaged on the development of centralized service observing and the centralized panel "A" switchboard.



H. G. W. Brown

A quarter of a century in the service of the Western Electric Company and Laboratories was rounded out by W. B. Prince on August 3. Mr. Prince came with the Western Electric after completing the electrical engineering course at Virginia Polytechnic Institute.

He is engaged on the design and development of local manual circuits and has had a prominent part in the development of straight-forward trunking and time announcement. Previous to this he was in charge of case costs, setting up circuits for testing, and the equipment and circuit files.

W. B. Prince

Mr. Prince also has had extensive experience on telephone repeaters. When the vacuum tube repeaters were first applied on a commercial basis in 1915, he supervised the building and testing of repeater sets, and continued in this work until they were standardized and the work transferred to Hawthorne.

During the war period he was engaged on production work of apparatus supplied to the United States Signal Corps. He also had a part in submarine detection work and made trips to Boston, Philadelphia and New London to install submarine detection devices on vessels in the navy yards at these places.

The twenty-fifth anniversary of J. B. Draper's association with the Bell System occurred on August 10.

With the New York Telephone Company Mr. Draper worked on both outside plant and central office work. He aided in the installation of the machine-ringing system in the Plaza office, one of the first in the Metro-

politan district. After a period in the equipment engineer's office assigned to testing activities, he returned to the Plant Department of the New York Company and worked for a while on the centralized test bureau, then newly established for New York City.

In 1918 Mr. Draper came with the Laboratories as a member of the toll group. He worked on the development of the start-stop signalling system on the New York-Philadelphia toll lines. He later was engaged on the development of the land equipment for the radio-telephone circuit between Long Beach, California and Catalina Island. Since 1922 he has worked on general step-by-step development and at the present time is specializing on PBX step-by-step systems.

J. B. Draper

H. C. Caverly was in Atlanta on an investigation of sender test equipment. The subscriber's senders in Atlanta handle calls to both panel and step-by-step offices.

Twenty years in the Bell System were completed by J. W. Gooderham and E. D. Butz during the past month.

Toll Development

T. V. Curley was at Chicago to investigate transmission problems connected with number checking in the Chicago area. On his return he stopped off at Akron on work pertaining to dialing on toll trunks from toll positions.

Tests on voice-frequency connecting circuits for harbor craft radio-telephony were made by H. M. Pruden and E. M. Squire at Mendham.

H. I. Romnes visited Norlina and Greensboro, North Carolina, to examine pilot wire recorders used on the 4,000-mile cable circuit trial.

At the Morristown repeater station E. P. Cordray made extensive tests on transmission measuring set trunks with the Return Loss Measuring Set. W. V. K. Large also made a visit to Morristown for these tests.

E. Vroom completed twenty years in the Bell System on August 1.

Special Development

L. Keller, Systems Studies Engineer, completed twenty-five years in the Bell System on August 1.

For seven years prior to his association with the Bell System Mr. Keller worked in the independent field. He served an apprenticeship at the Automatic Electric Company, the object of which, as he explains it, was to become familiar with the dial system from "A" to "Z." He learned to adjust switches and dials, to wire and test banks, and finally was sent out on installation work. The intricate details of dial system operation and installation he assimilated rapidly and competently. Within a short period he was given complete charge of installations in various sections of the country. After supervising at Columbus, Ohio, the largest dial installation up to that time, he was detailed to Los Angeles where difficulties were experienced with the recently installed dial system. He was successful in straightening matters out, and was induced to remain in Los Angeles by the local company as its chief engineer.

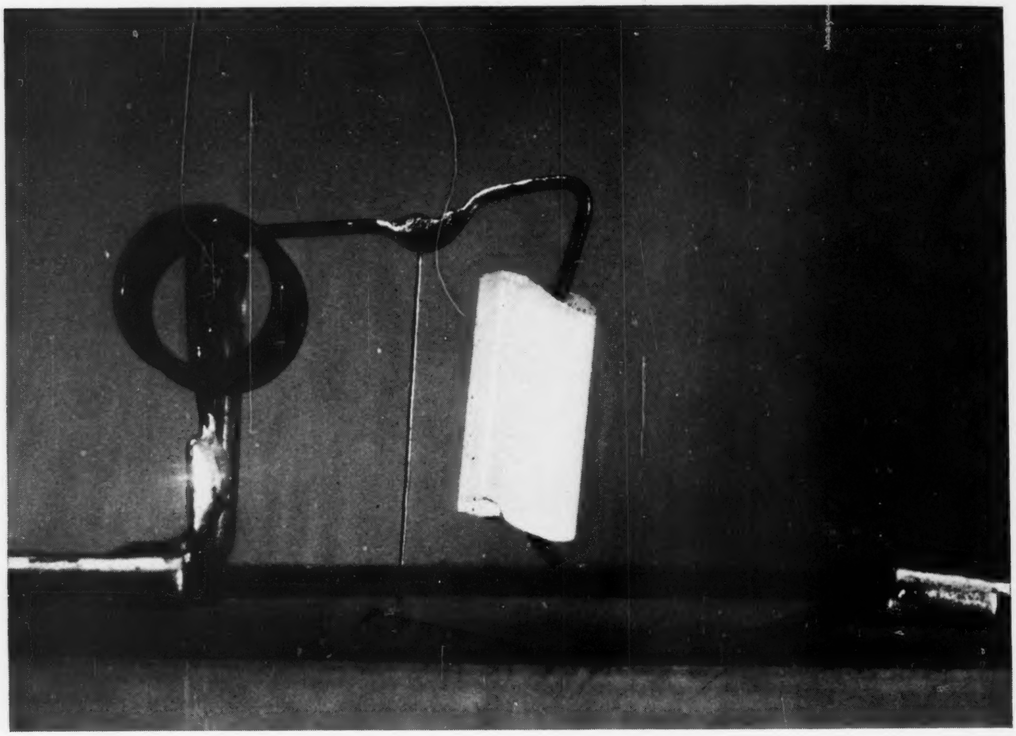
L. Keller

Mr. Keller's Bell System service dates from

this time. In 1917 the local operating company consolidated with the Pacific Telephone and Telegraph Company, forming the present Southern California Telephone Company, and became associated with the Bell System. Mr. Keller became chief engineer of the consolidated company and was in charge of the extensive work of interconnecting the lines of the two companies.

In 1918 he came with the Western Electric Company in New York. He was among those that participated in the executive conferences when decision was made to inaugurate dial service in New York City and aided in preliminary plans.

At the present time Mr. Keller's work involves the investigation of new developments and inventions of outside organizations and individuals for possible application to Bell System uses.



The familiar No. 35-type alarm fuse bulks large in importance in central-office protection

Profile Lathe for Miniature Work

By G. F. ATWOOD
Plant Shops Consultant

HOW far an engineering art has progressed may perhaps be indicated by the degree of refinement which the art feels it can demand in its products. This is well shown by the advanced arts of telephony and its allies, which require extreme precision in most of their apparatus. Such precision is based in almost all cases on exact mechanical dimensions.

But the degree of mechanical precision which is adequate in many arts is not always adequate in the arts of communication. Elsewhere exactness is required principally to insure mechanical fitting and interchangeability of parts, and need not exceed what can be secured by mechanical gauging. Communication apparatus, on the other hand, is employed to produce effects which are judged by the subtle senses of hearing and sight. Defects of equipment which are mechanically imperceptible may seem disastrously large to ear and eye.

As a result of this critical nature of the dimensions of telephone apparatus, the Development Shop, the organization in which the creations of these Laboratories first take physical form, is today required to make the most diverse experimental models accurate to specification. Often these models involve very small parts, of irregular profile, in which every length, angle, and radius of curvature must be correct. These parts may be

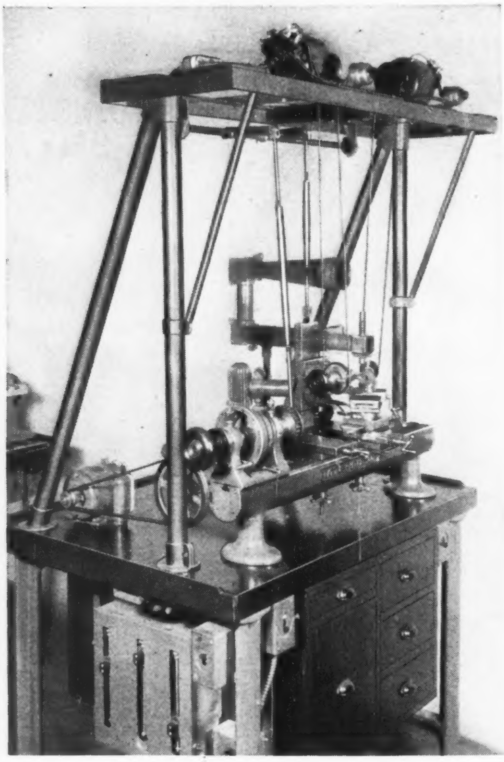


Fig. 1—The new lathe in the Precision Room consists of a standard bench lathe extensively redesigned and augmented by the Development Shop

as soft as rubber or as hard as diamond. Instrument pivotal systems, phonograph recording styluses and reproducing needles, light-valve parts, optical slits, and quartz crystals for frequency control are examples of such parts and indicate their diversity. All require workmanship of the highest order, performed under the microscope.

It is, of course, impossible to design and install in the Precision Room special machinery to manufacture each of these parts on an experimental basis. The Shop must aim to make one tool serve many purposes. Accordingly it has designed and installed in the Room a lathe of unusual flexibility, adapted for development purposes to many specialized machining operations.

The familiar lathe of the ordinary machine shop consists essentially of a rigid cast iron bed on which a power-driven spindle is mounted in a "headstock" at one end, and a "tailstock" is mounted at the other. Materials to be turned are either "chucked" on the headstock or pivoted on centers between the headstock and the tailstock, and are machined by tools held in a movable carriage on the bed. The special lathe in the Precision Room, shown in Figure 1, carries no tailstock, since the materials to be machined on it are so short that they can be firmly chucked on headstock alone. Instead it has two additional headstocks whose spindles can be independently and simultaneously driven by motors of variable speed. The first or "main" headstock is only occasionally used as a headstock; ordinarily its use is confined to producing a reciprocating motion to drive certain of the various sliding carriages supporting the other two headstocks. Both these latter are suited for chucking either work or tools; and their carriages can be adjusted and moved in the most varied ways, by hand or by drives from the main headstock.

The motor at the rear of the bench drives a slow-speed "jack shaft" which furnishes power through sprockets and chain to the main headstock. From this head, by means of a crank pin, a connecting rod, a rocking shaft, and a second connecting rod, a reciprocating movement is given to the vertical slide on which the second headstock is mounted. The spindle of this head is driven through an elastic belt by a motor mounted on the superstructure. From Figure 2,

it can be seen that the second head can be set at various angular positions about the horizontal axis of its mounting to the vertical slide, and about the vertical axis of this slide's mounting to the compound slide on the lathe bed. By screw feeds in the compound slide, the head can be moved in the plane of the bed. When continuous rotation of the work or tool is not desired, the headstock can be replaced by a vise or an indexing milling fixture.

The third headstock, whose spindle is driven by a belt from another motor on the superstructure, is mounted on a screw-adjusting slide which in turn is pivoted about a vertical axis to a compound slide clamped to the lathe bed. This head can be given a continuous oscillating movement about the vertical axis by a drive (Figure 3) from the jackshaft through a belt, a worm and wheel, a crank with adjustable crankpin, and

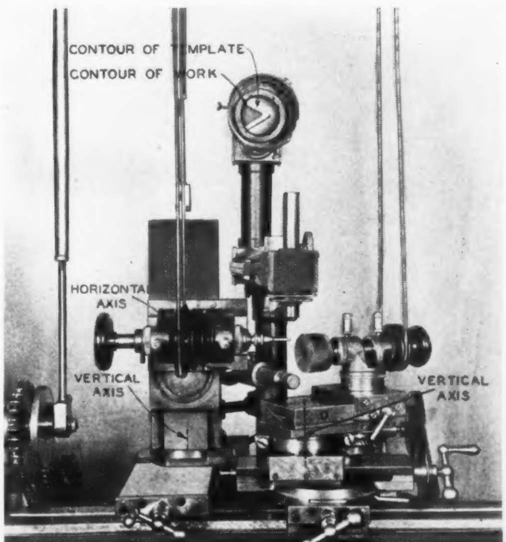


Fig. 2—The two headstocks are very flexibly mounted

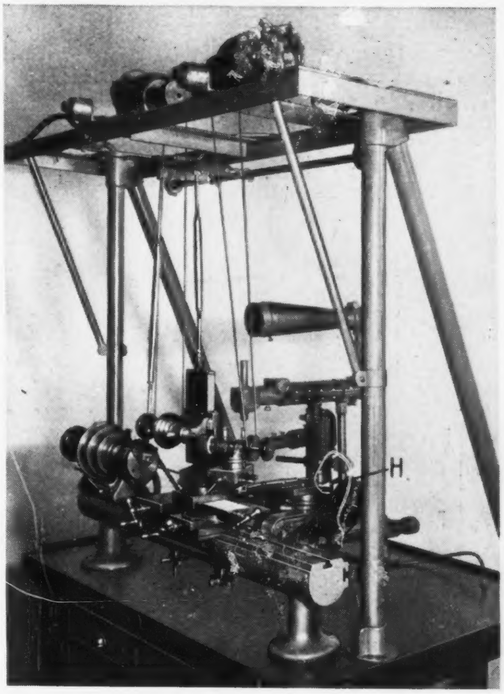


Fig. 3—The drive at H provides an oscillation of the third headstock, the amount of which can be adjusted at an adjustable crank pin, making it possible to generate spherical surfaces

a connecting rod. By the upper slide, the radius of rotation of the head about the axis can be adjusted; and by the compound slide the head can be fed either across or along the lathe bed. A stationary tool holder can be substituted for the third head, as for the second head.

Machining operations of all types are performed on this lathe. The variable speed of the driving motors enables free use of tools for turning, milling, sawing, drilling, grinding, lapping and polishing. When brittle materials such as diamond, sapphire, quartz or glass are being machined, a special adapter is interposed between the third headstock and its slide, to limit the pressure of the cut by providing a yielding cushion between work and tools.

Since it is always difficult to ensure concentricity in rechucking refined work, the possibility of forming a complicated part on this lathe at a single chucking is one of the most valuable results of its versatility. Thus

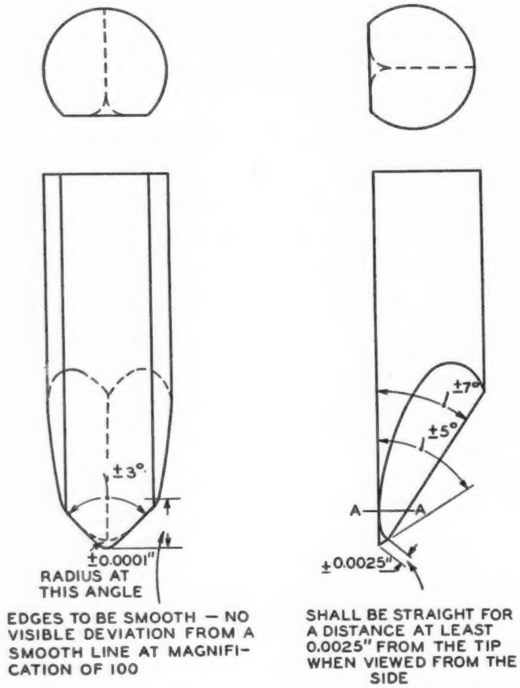


Fig. 4—The versatility of the new lathe permits the accurate fabrication of an entire sapphire stylus at a single chucking

every surface and clearance angle of a recording stylus (Figure 4) can be formed with great accuracy by the successive use of appropriate tools with suitable adjustments and motions of the lathe.

By chucking a piece of work in the second head and a tool in the third, and oscillating the latter on its pivot, a spherical surface can be generated, of radius equal to the distance of the tool from the pivoting axis. Then, combining the oscillation of the third head with the vertical reciprocation of the second, the surface can be lapped and polished. It is in this way that the spherical points of the playback needles, a thousandth of an inch in radius, are machined (headpiece).

Since most of the work for this lathe is too small to measure accurately by the usual methods without being removed from the machine, the measurements are made on the spot by a periscope projector (Figure 5). This instrument, when moved over the work, projects a magnified image of the work on a ground glass screen, on which is also marked an enlarged drawing of the work. Magnification and scale of drawing are usually fifty to one. Inasmuch as highly corrected lenses and prisms are used in the projector, matching the projected image

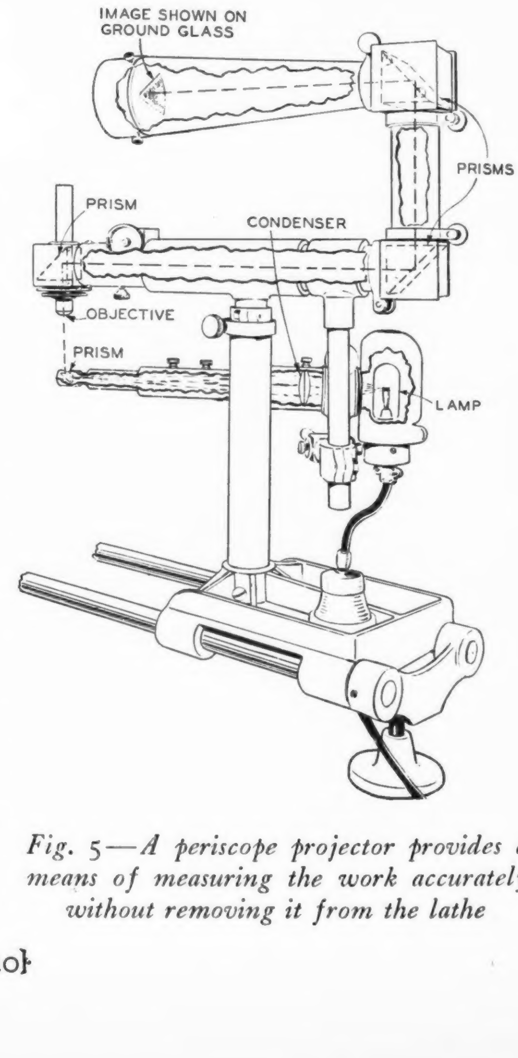


Fig. 5—A periscope projector provides a means of measuring the work accurately without removing it from the lathe

of the work with the drawing ensures a satisfactory measurement of profile and dimensions.

To assist in setting up the work, measuring deviations from concentricity, and examining the character of finished surfaces, a microscope is often used. Not shown in the illustrations, it is mounted on a pedestal arm carried on the lathe bed in the position occupied on the standard lathe by the tailstock, and can be moved over the work in the same way as the projector.

This complicated series of slides and spindles, motions and microscopes, would fail of its intended purpose if it suffered from measurable mechanical imperfections. Great care must be taken to eliminate vibrations due to unbalance of rotating parts, joints in the belts, and the like. There must be no end or radial play between the headstocks and their spindles; the slides must be free from side play, and move in perfectly straight paths. Omitting the utmost precautions would leave far too great a ratio of the play to the size of cut for satisfactorily precise results.

In producing any one part the lathe cannot, of course, compete with machines designed to produce that part to standardized dimensions on a manufacturing basis. Its use is as an adjunct to development, where continual experimental change is the rule. In the hands of the skilled mechanicians of the Precision Room, it will play a large part in the pioneering work of these Laboratories toward an ever more exact telephone art.

A Fruitful Application of Mathematics

By S. A. SCHELKUNOFF
Mathematical Research

At one time or another probably every reader has been puzzled by some problem which belongs to a branch of mathematics, fascinating in itself, but very little known to laymen. In recent days, there has been interest in the problem of the sailors, coconuts, and monkeys.

It seems that five sailors, wrecked on a South Sea island and in search of food, knocked down enough coconuts to last them for months but were too tired to divide them into equal shares on the same day. That night one of the sailors woke up and decided to take his share; but on dividing the supply into five equal piles, he discovered that one coconut was left over. In order to make his problem simple, he threw the extra coconut to the monkeys and took one of the piles away. Later on, another sailor awoke and decided to take his fifth. Not knowing that the first sailor had already taken his share, he divided the supply into five equal parts, but found one coconut left over. Like the first sailor, he threw it to the monkeys and took what he thought belonged to him. As the night wore on, the remaining sailors did the same, always finding themselves in the predicament of having an extra coconut and always disposing of it in the same manner. In the morning the five sailors divided what was left into five equal piles, and this time they accomplished the division without having to throw away any coconuts. The problem is to find how many coconuts there were at the beginning.

This problem is one in Diophantine Analysis, the branch of mathematics dealing with the solution of systems of equations in which the number of unknown quantities exceeds the number of equations and the solutions are required to be in integers. The analysis is named for Diophantus, a Greek mathematician, who seems to have been the first to become interested in such problems. One of the most brilliant of mathematicians, Diophantus lived about 250 A.D., but there is definitely known about him only that he died at the age of 84, from his epitaph reading: "Diophantus passed one-sixth of his life in childhood, one twelfth in youth and one-seventh more as a bachelor; five years after his marriage was born a son who died four years before his father, at half his father's ultimate age."

The problem of the coconuts can be set up as an equation of the type $ax+by=c$. Of course there is no trick in solving this equation if x and y are unrestricted, for one can choose any value whatever for one of these unknowns, substitute it in the equation and solve for the other unknown, thus obtaining an indefinite number of solutions, one for each choice. When x and y are required to be integers,

the solutions, though far less numerous in any particular range of values, may still be indefinite in total number. If, however, x and y are required to be not only integral but positive, the equation may possess only a finite number of solutions or even none at all (Figure 1).

It can be shown that, if $x=p$ and $y=c$ constitute an integral solution of the equation, all the other integral solutions can be obtained from this by substituting all the integers successively for t in the formulas $x=p+bt$ and $y=q-at$. Thus the problem can be reduced to that of finding any one solution to the original equation.

Diophantus solved each equation by a method peculiar to it; in common with most of the ancient mathematicians, he was interested in obtaining a specific solution rather than in developing general methods of procedure. General methods have since been developed for handling the simpler types of Diophantine problems, including that under which the problem of the coconuts falls. There are many more types, however, for whose solution general methods are not even today available. It is interesting, therefore, to consider a special method of solution such as Diophantus might have used for this problem, for it illustrates in a simple way the homely modes of procedure upon which mathematicians must still rely in many more complicated kinds of Diophantine problems.

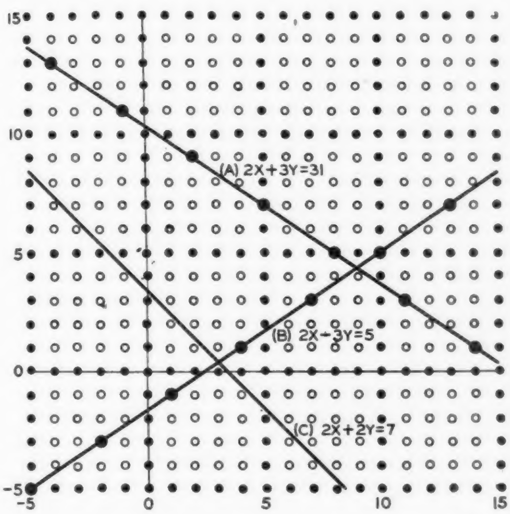


Fig. 1—Finding the integral solutions to an equation in two variables corresponds to finding the points with integral coordinates through which the graph of the equation passes. In the above graphs of three linear equations, it can be observed that one (A) has only a finite number of solutions in positive integers, another (B) an infinite number, and the third (C) no integral solutions either negative or positive

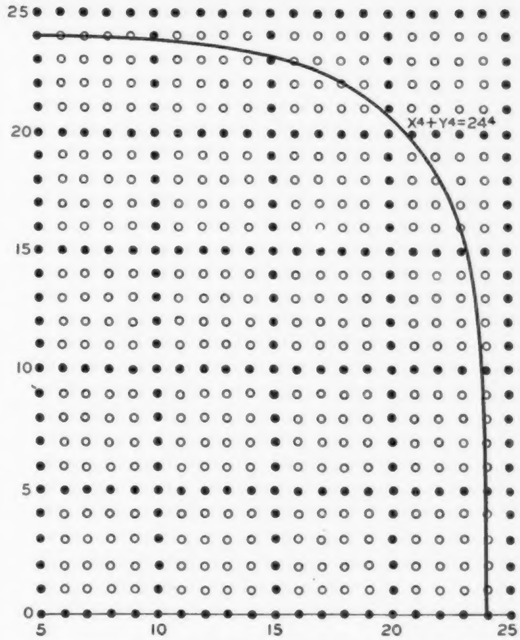


Fig. 2—It is strange but true that the family of curves of the type $x^4+y^4=z^4$, of which one member is shown, pass through no points with integral coordinates

Roughly this mode of procedure may be described as paring down the equation until a solution can be obtained by inspection. The paring down is accomplished by applying the theorem that every integer, and thus

each quantity in the equation, can be expressed as the product of one and only one set of prime factors. Thus if the coefficients on one side of the equation are observed to have a number d as a factor, the other side must also have this factor,—if not in its coefficients, then in its unknowns, since the equation asserts that both the sides are the same number. The unknown can then be replaced by d times a new unknown, and d can be cancelled from both sides of the equation. By successive application of this device, the coefficients of the equation in the new unknowns are made small enough to permit a solution by inspection. The values of the original unknowns can be obtained from the solution for the new by multiplying the latter by such factors as were cancelled out. The detailed solution of the problem of the coconuts by this method is shown below.*

Perhaps the most famous problem in Diophantine Analysis is that known as "Fermat's Last Theorem", after the French mathematician who first stated it, without proof, to the effect that the equation $x^n+y^n-z^n$ cannot be solved in integers if n is greater than 2 (Figure 2). Euler proved the theorem for $n=3$ and $n=4$; Dirichlet for $n=5$ and $n=6$; G. Lamé for $n=7$; and Kummer for many other values. The problem has never been solved with complete generality, although numerous and handsome prizes have been offered by various scientific societies for the complete solution, and new branches of mathematics have been discovered in attempts to provide such a solution.

**If x equals the original number of coconuts, the first sailor took $\frac{1}{5}(x-1)$ coconuts and left $\frac{4}{5}(x-1)$; the second took $\frac{1}{5}[\frac{4}{5}(x-1)-1]$ and left $\frac{4}{5}[\frac{4}{5}(x-1)-1]$. The fifth sailor thus left $(\frac{4}{5})^5(x-1)-(\frac{4}{5})^4-(\frac{4}{5})^3-(\frac{4}{5})^2-\frac{4}{5}$. Since this remainder was evenly divisible by 5, it can be called $5y$. On simplifying this equation, it becomes $4^5x-4.5^5+4^6=5^6y$. But what the fifth sailor left was also divisible by 4, so let $y=4v$. Then $4^4x-5^5+4^5=5^6v$; or $4^4(x+4)=5^5(1+5v)$. Since 5^5 is a factor of both sides of the equation, let $x+4=5^5w$. Then $5v+1=4^4w$; or $5v+1=256w$. An obvious solution of this equation is $w=1$ and $v=51$. Then all solutions for w and v can be found from $w=1+5t$ and $v=51+256t$. Hence the formulae for x and y are $x=3121+15625t$ and $y=204+1024t$, where t is zero or any positive integer. Thus the smallest number of coconuts there could have been is 3121, of which each sailor would receive 204 the following morning.*

Radiator Cooling Units for Reserve Power Plants

By V. T. CALLAHAN
Power Development

RESERVE alternators and direct current generators, driven by internal-combustion engines, are often essential parts of central-office power plants where more than one source of reliable outside power service is not available. Although employed for the most part only when the regular power supply has been cut off, they are of vital necessity on these occasions, and every effort has been made in their design to secure reliability. A range of sizes has been provided to meet the requirements of the various sizes of offices and the general features of each size have already been described in the RECORD*. Engines of the smaller sizes are air-cooled while those of the BA type, representing an intermediate group, are cooled by a steady stream of water, or by circulating water through automobile type radiators, a method which reduces the water required to the small amount necessary to replace that lost by evaporation. Until recently all the larger units have been cooled by city water without recirculating.

Although the water requirements when artificial cooling is not resorted to are much greater, they are not, in most cases, a matter of any very great importance since the engines are used only occasionally and usually for short periods of time. In some localities, however, particularly in the arid districts in the western part of the country, water may be very scarce at certain seasons of the year. Because of this it has seemed desirable in the interests of conservation to provide, especially for the larger engines, some method of cooling the water and recirculating it.

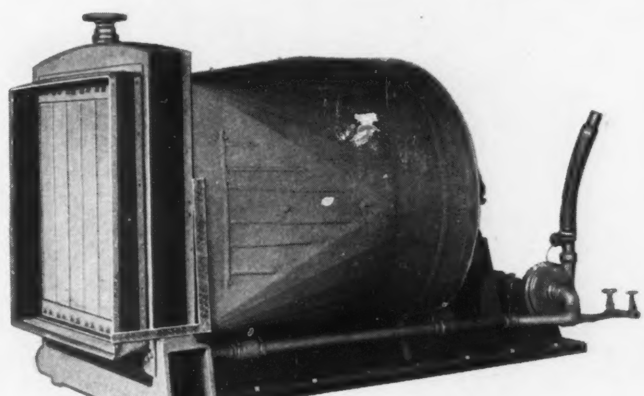


Fig. 1—A side view of the new radiator cooling unit showing circulating pipe and flexible joint for connection to the duct work leading to the building wall

* RECORD, *June*, 1928, *p.* 318; *September*, 1928, *p.* 21; *December*, 1929, *p.* 158.

Either cooling towers or radiators would satisfy the requirements but a study indicated that radiators would be more satisfactory since they are more easily installed, require less replacement water, and both maintenance and first cost are lower. Both sizes of the type R engine were to be provided for. One is a four cylinder 50-HP engine direct-connected to a 34-kw alternator, and the other a 75-HP engine driving a 51-kw alternator. The radiators finally adopted were alike for both engines but the fan motor for the four-cylinder engine runs at 514 rpm and is rated at 4 HP while that for the six-cylinder unit runs at 600 rpm and is rated at 5 HP.

Commercial radiators are generally guaranteed to keep the engine cooling water below the boiling point with full load on the engine and under sea-level barometric pressure and a room temperature not greater than 105 degrees Fahrenheit. At higher elevations, and thus at lower barometric pressures, the cooling effect of the unit is decreased both because of the lower density of the air and of the lower boiling temperature of the water. A study of the conditions under which the engines might be used for telephone power plants showed that elevations of nearly 6000 feet might be encountered and room temperatures as high as 117 degrees. It was evident, therefore, that existing commercial units would not be satisfactory and specifications were laid down that under normal barometric pressure at Buffalo, New York, where the engines are manufactured, the cooling units would keep the water temperature below 195 degrees Fahrenheit with a room temperature of 120 degrees and with the engine carrying 10 per cent overload.

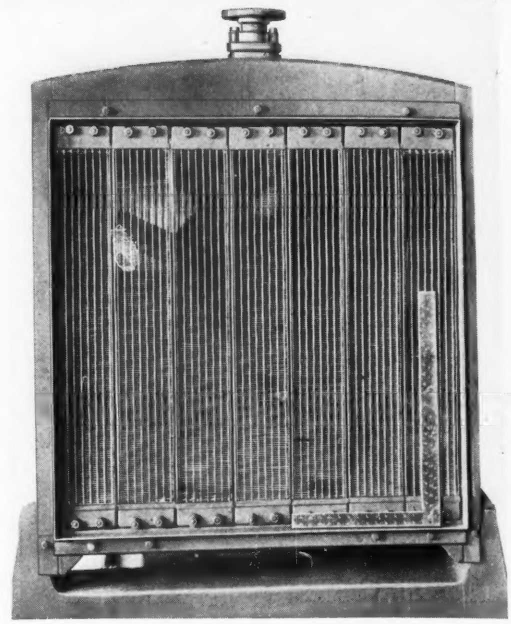


Fig. 3—The radiator is built in seven sections to simplify replacement and cleaning

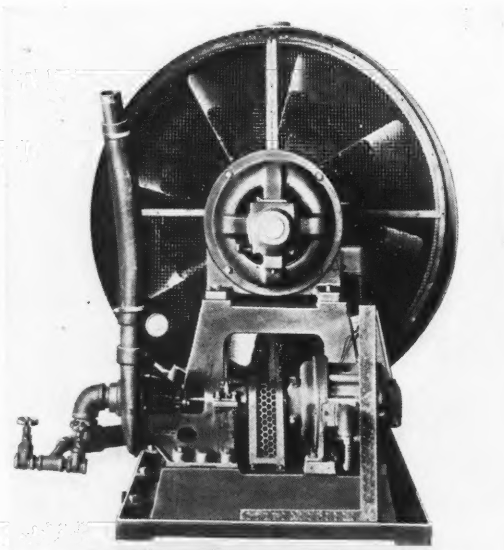


Fig. 2—Motors for driving both fan and pump are designed for being driven by the reserve generator

The complete cooling unit as finally developed consists of a radiator element, a fan with a driving motor, and

a centrifugal pump also motor driven, all mounted on a common cast-iron base equipped with spring supports similar to those used with the R-type engine as already described in the RECORD. Its general appearance is shown in Figure 1. The fan is set back from the radiator and connected to it by a sheet iron duct. To the opposite face of the radiator a five-inch flexible section is attached to connect to other duct work which will run through the building wall to the outside. Air is thus taken from inside the power-room, forced through the radiator, and out of the building. It is customary to provide doors in the duct between the radiator and the building wall, which will both give access to the radiator for cleaning or repairs and allow some of the heated air to be returned to the room in cold weather. A protecting box is generally built outside the building wall at the mouth of the duct, with doors at the sides and bottom, which may be adjusted to offset the effect of unfavorable wind directions.

The fan is designed to give low air velocities so as to reduce the friction through the radiator and to give quiet operation. The motors on both fan and pump are wound for connection to the engine-driven alternator so that the complete unit is independent of all outside sources of power. The power end of the unit is shown in Figure 2.

Oval copper tubing, approximately one-eighth by seven-eighths inches, is used for the radiator element. The lengths of tubing, of which there are about five hundred altogether, are run vertically with their narrow side presented to the air current. A staggered arrangement is employed, the odd-numbered rows of tubing are in line with each other in the direction of air flow while the even-numbered rows are located in line with the space between the tubes of the odd-numbered rows. For convenience of manufacture and maintenance the radiator is built in seven units as shown in Figure 3, and any one section may be replaced without affecting the others.

The arrangement of the circulating system is shown in Figure 4. Hot water enters the top of the radiators,

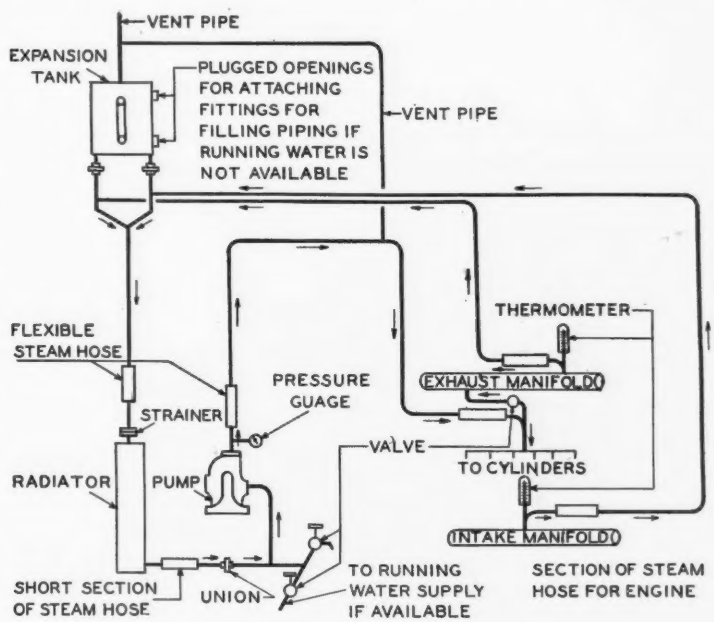
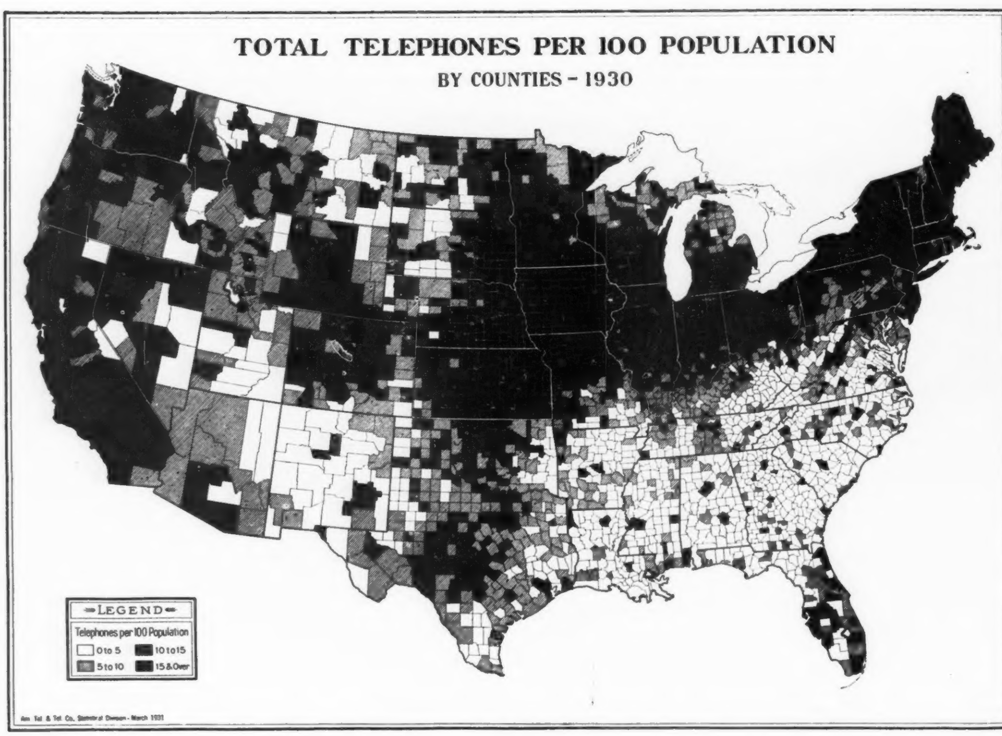


Fig. 4—Diagrammatic arrangement of piping for radiator cooling unit

and the pump takes the cooled water from the bottom outlet and lifts it to the engine. Here the line divides. Part of the water is passed around

the cylinders and then around the intake manifold, and part around the exhaust manifold. The heated water from these two sources is forced up and over to the vertical line feeding down to the radiator. An expansion tank is provided at the top of this vertical line to carry a reserve supply of water and to allow any water vapor to escape. Connections between the piping and the radiator, as well as those to the pump and the engine are made by flexible steam hose to allow for expansion and to prevent the transmission of vibration to the building. A pressure gauge is connected to the outlet of the pump, and thermometers are inserted in the outlets from the exhaust and intake manifolds so that the operating conditions may be determined at any time.

By making the R-type engine entirely independent of outside water supplies the development of this new radiator cooling unit has extended the usefulness of the larger sizes of the intermediate group of reserve power plants and has thus contributed further to the reliability of telephone service.



This map of telephonic development was prepared by the Statistical Division of the American Telephone and Telegraph Company, from whom copies on a larger scale can be secured

Highway Wiring Diagrams

By W. L. HEARD
Equipment Methods

TELEPHONE systems drawings, because of the large number of pieces of small apparatus they include, are probably more complicated than any other form of draftsmanship. Each relay on such a drawing—and it is chiefly of relays that many of the circuits are constructed—has many wires connected to it, and the multiplication of wires per relay by the large number of relays results in an interlacing network of extreme intricacy. A sender circuit, for example, may have some three hundred pieces of apparatus each with four or more terminals and each terminal will have one or more wires connected to it so that the number of wires to be drawn for such a circuit runs into the thousands. Since for convenience of handling it is desirable to limit the size of a drawing, several of them are frequently required to depict completely a single equipment assembly.

Rather than locate the various pieces of apparatus on a drawing in their relative positions, it is customary, because of this very large amount of wiring, to place the apparatus so as to make the wiring paths as short and free from crosses as possible. This, of course, makes the drawing less convenient for use in actually wiring the apparatus but it is a necessary compromise to secure greater overall clarity. Both the amount of apparatus that may be shown on a drawing and its arrangement in the correct relative positions must be sacrificed to obtain reasonable legibility.

A change in method recently adopted by the Systems Drafting group, however, has made it possible to avoid both of these concessions. It allows the apparatus on the drawings to be shown in their true relative locations, and at the same time makes it possible to show more apparatus with much greater simplicity than has heretofore been possible. This new form of drawing is known as a "highway" wiring diagram. The large numbers of wires running between different parts of the drawing are gathered together into sets of highways each represented by a single heavy line. A typical drawing of this sort is shown as Figure 1. When possible the highway lines are drawn where the local cabling will be run but this is not essential to the system. The distinguishing feature is that highways be run between the rows of apparatus to gather up the large number of leads converging from each piece and to carry them either to other rows of apparatus or to the edge of the drawing where their destination is plainly marked.

Each feed wire from a piece of apparatus is numbered where it enters and leaves the highway, and the direction of travel in the highway is indicated by pointing the line entering or leaving in the direction of

travel. To simplify the coding only two-digit numbers are used, and additional highways are run when there are 100 or more wires to be grouped together. Each highway is designated by a letter and each has its own series of numbered conductors. To make the drawings uniform and the recognition of the feed wires easy, all identification numbers and colors of wires are written either at the left of or above the lines to which they apply.

The scheme as a whole has proven of real value both by saving drafting time and in furnishing simpler drawings for general use. By its use much more may be put on a single drawing than could be with the former method. One drawing of the highway type may include as much as three or four made by the former method. In addition to this gain the drawing is made easier to follow and therefore aids greatly in the manufacture, installation, and maintenance of telephone equipment.

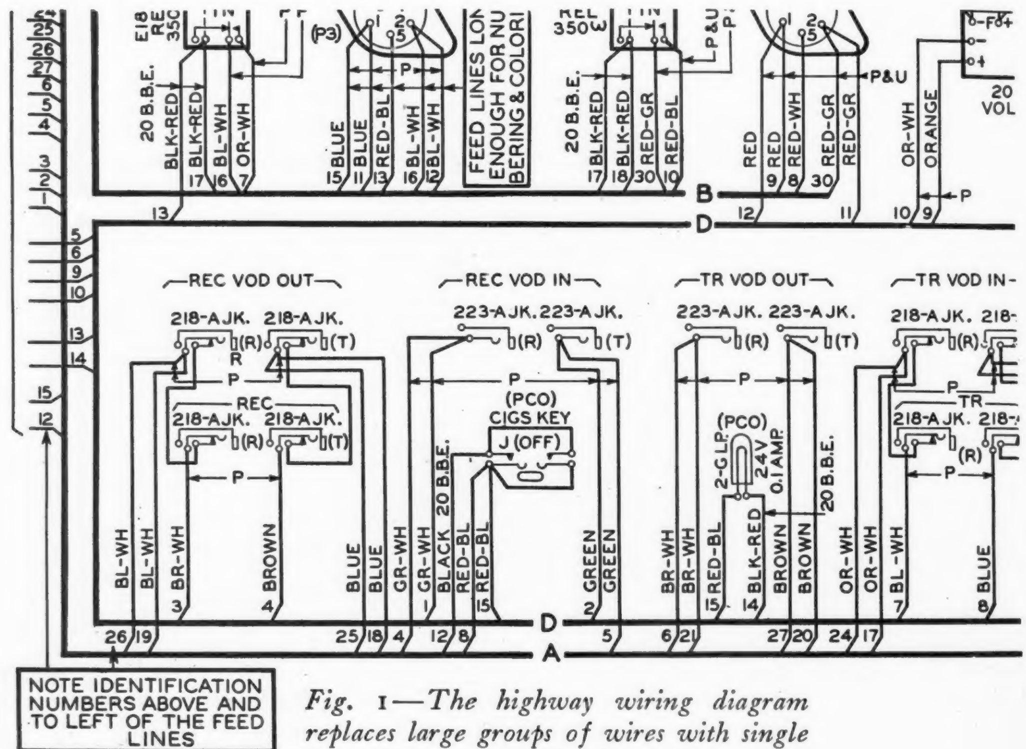
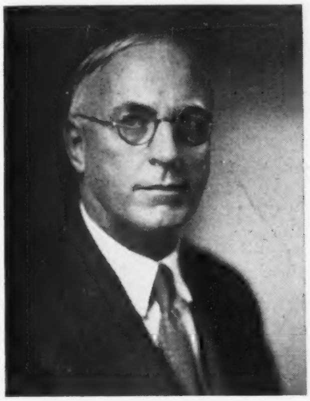


Fig. 1—The highway wiring diagram replaces large groups of wires with single heavy lines at a considerable saving in space

Contributors to this Issue

G. W. Elmen received a B.Sc. degree from the University of Nebraska in 1902 and an A.M. degree two years later. After leaving the University he spent two years in the laboratories of the General Electric Company. In 1906 he joined the engineering department of the Western Electric Company—since incorporated as Bell Telephone Laboratories. Here his entire time has been devoted to magnetics research. He was instrumental in the development of powdered-iron core material, which greatly improved the characteristics of loading coils; and both permalloy and perminvar are credited to his achievements. Over forty patents have issued to him. In 1927 he received from Philadelphia the John Scott Medal for the invention of permalloy, and the following year the Elliott Cresson medal by the Franklin Institute.

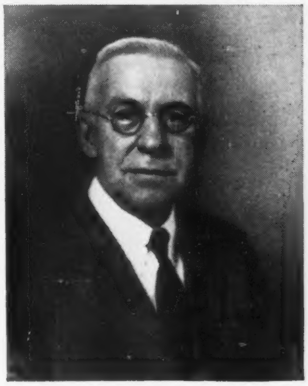
G. C. Crawford received an A.M. from Harvard in 1903 and in the following year an S.B. in Electrical Engineering. After a year spent in teaching physics at the University of North Carolina he joined the Engineering Department of the Western Electric Company. For three years, beginning 1908, he was an instructor in physics at the College of the City of New York, but returned to the Western Electric Company in 1911. Here he was engaged in the development of ringing systems, and during the war period he took part in the development of radio sets for airplanes and submarine chasers. Since then he has been occupied with the development of repeaters for message and broadcasting systems, and of transmission measuring sets, and at present he is in charge in the Toll Systems Department of the group handling this work.



G. W. Elmen

Prior to entering the Contract Department of the Western Electric Company in 1895, in the old Thames Street building, G. F. Atwood had spent several years in charge of experimental work on phonographs, electric street-railway systems, and iron-ore separating machines at the Edison Laboratory. He left the Company in 1898 and, reentering fourteen months later, was given charge of the Tool Room of

G. C. Crawford



G. F. Atwood

S. A. Schelkunoff

L. E. Abbott

V. T. Callahan

W. L. Heard

the Shop. When the Shop was moved to the West Street building, he was assigned supervision of the manufacture of new types of apparatus, such as toroidal loading coils, and pneumatic ticket-distributing systems for toll offices. When the Engineering Department was created, he was made supervisor of the Model Shop. Mr. Atwood resigned in 1907 to engage in the manufacture of insulated wire and re-entered the employ of the Laboratories in 1913. During the war he was active with the group of engineers engaged in the design and test of submarine detection apparatus, and thereafter he was concerned with the design of machine switching equipment. In 1927 he transferred from the Apparatus Development Department to the Development Shop, where he has been instrumental in developing methods for manufacturing piezo-electric quartz plates for radio and other circuits. He has also cooperated in establishing the Precision Room as an addition to the Development Shop in which intricate or difficult jobs can be handled under the best possible conditions of mechanical equipment and technical skill.

Sergei A. Schelkunoff received the B.A. and M.A. degrees in mathematics from the State College of Washington in 1923, and in the fall of that year joined the Carrier Research group of these Laboratories. Three years later he returned to Washington State as an instructor in mathematics and later became an associate professor. In 1928 he received the Ph.D. degree from Columbia University. The following year he rejoined the Laboratories, entering the Mathematical Research group where he has since been pursuing electromagnetic studies in their relation to communication problems.

L. E. Abbott was graduated from Brooklyn Polytechnic Institute in 1928 with an M.E. degree. As a member of the Laboratories he has worked on fatigue studies of sheet non-ferrous alloys and lead cable sheath and lately has been engaged in welding and x-ray development. At the recent June graduating exercises he received an M.S. in M.E. degree from Brooklyn Polytechnic Institute.

After graduating from Pratt Institute in 1916, V. T. Callahan took the Student Course with the Diehl Manufacturing Co. and later similar work with the Public Service Electric Corp. In 1917 he went with the Lake Torpedo Boat Co., where he was engaged in the design, construction, and testing of both electrical and mechanical equipment. Following five years service in this field he joined the Laboratories where he has been engaged in the design of reserve power plants for Central Offices.

After obtaining the degree of B.S.E.E. from Kansas State College in 1911, W. L. Heard entered the employ of the Automatic Electric Company in Chicago. The next year, however, he became affiliated with the Western Electric Company in Hawthorne and remained with it until 1918 when he transferred to the Laboratories. Both at the Hawthorne plant and in New York, his field of work has been equipment engineering.